(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number : **0 613 109 A1**

(12) **EUROPEAN PATENT APPLICATION**

(21) Application number : **94301261.7**

(22) Date of filing : **23.02.94**

(51) Int. Cl.^{5} : **G08G 5/06**

(30) Priority : **26.02.93 US 23978**

(43) Date of publication of application : **31.08.94 Bulletin 94/35**

(84) Designated Contracting States : **DE ES FR GB IT NL SE**

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(54) **Infrared vehicle identification system.**

(57) An infrared vehicle identification system [109] comprising a microprocessor controlled infrared (IR) transmnitter [112] located on an aircraft nose wheel landing strut [111] and an infrared receiver [128] including a microprocessor [44] enclosed in a plurality of edge light assemblies [20] located along surface pathways of an airport including runways and taxiways. The infrared transmitter [112] comprises an array of light emitting diodes [120] (LEDs) arranged in a semicircle within the horizontal plane. The transmitter [112] emits a plurality of fields [121, Fig.13] of encoded data to provide vehicle identification and position information. One field [122] comprises a steady stream of pulses that allows the IR receiver [128] to calculate the baud rate of the transmitter [112] and automatically adjust its internal timing. The other fields include a unique word [123] for marking the beginning of a message, the number [124] of characters in the message, the' vehicle identification number [125], the vehicle position [126] and a checksum [127]. The latter [127] ensures that a complete and correct message has been received. If the transmitted message is interrupted for any reason, the checksum [127] will detect it and the messages will be voided. The IR receiver [128] relays a valid message of vehicle identification [125] and position [126] to a central computer system [12, Fig.1] at the airport control tower via the edge light assembly power wiring [21, Fig.1].

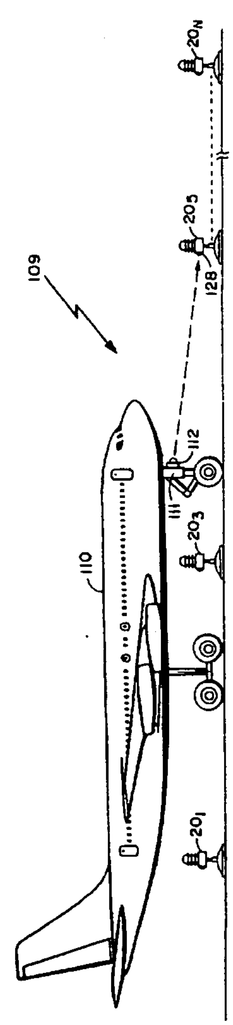

FIG. 10

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Background of the Invention

This invention relates to identification of airport surface traffic and in particular to an apparatus and method for detecting and identifying aircraft or other vehicle movement on airport taxiways, runways and other surface areas.

Currently, ground control of aircraft at an airport is done visually by the air traffic controller in the tower. Low visibility conditions sometimes make it impossible for the controller to see all parts of the field. Ground surface radar can help in providing coverage during low visibility conditions; it plays an important part in the solution of the runway incursion problem but cannot solve the entire problem. A runway incursion is defined as "any occurrence at an airport involving an aircraft, vehicle, person, or object on the ground that creates a collision hazard or results in loss of separation with an aircraft taking off, intending to take off, landing, or intending to land." The U.S. Federal Administration Agency (FAA) has estimated that it can only justify the cost of ground surface radar at 29 of the top 100 airports in the United States. However, such radar only provides location information; it cannot alert the controller to possible conflicts between aircraft.

In the prior art, an airport control and monitoring system has been used to sense when an airplane reaches a certain point on a taxiway and controls switching lights on and off to indicate to the pilot when he may proceed on to a runway. Such a system sends microwave sensor information to a computer in the control tower. The computer comprises software for controlling the airport lighting and for providing fault information on the airport lighting via displays or a control panel to an operator. Such a system is described in sales information provided on a Bi-directional Series 7 Transceiver (BRITEE) produced by ADB-ALNACO, Inc., A Siemens Company, of Columbus, Ohio. However, such a system does not show the location of all vehicles on an airfield and is not able to detect and avoid a possible vehicle incursion.

A well known approach to airport surface traffic control has been the use of scanning radars operating at high frequencies such as K-band in order to obtain adequate definition and resolution. An existing airport ground traffic control equipment of that type is known in the art as Airport Surface Detection Equipment (ASDE). However, such equipment provides surveillance only, no discrete identification of aircraft on the surface being available. Also there is a need for a relatively high antenna tower and a relatively large rotation antenna system thereon.

Another approach to airport ground surveillance is a system described in U. S. Patent No. 3,872,474, issued March 18, 1974, to Arnold M. Levine and assigned to International Telephone and Telegraph Corporation, New York, NY, referred to as LOCAR (Localized Cable Radar) which comprises a series of small, lower powered, narrow pulses, transmitting radars having limited range and time sequenced along opposite sides of a runway ramp or taxiway. In another U. S. Patent No. 4,197,536, issued on April 8, 1980, to Amold M. Levine, an airport surface identification and control system is described for aircraft equipped with ATCRBS (Air Traffic Control Radio Beacon System) and ILS (Instrument Landing System). However, these approaches are expensive, require special cabling and for identification purposes require expensive equipment to be included on the aircraft and other vehicles.

Another approach to vehicle identification such as types of aircraft by identifying the unique characteristic of the "footprint" presented by the configuration of wheels unique to a particular type of vehicle is described in U.S. Patent No. 3,872,283, issued March 18, 1975, to Gerald R. Smith et al. and assigned to The Cadre Corporation of Atlanta Georgia.

An automatic system for surveillance, guidance and fire-fighting at airports using infrared sensors is described in U. S. Patent No. 4,845,629, issued July 4, 1989 to Maria V. Z. Murga. The infrared sensors are arranged along the flight lanes and their output signals are processed by a computer to provide information concerning the aircraft movements along the flight lanes. Position detectors are provided for detecting the position of aircraft in the taxiways and parking areas. However, such system does not teach the use of edge lights along the runways and taxiways along with their associated wiring and it is not able to detect and avoid a possible vehicle incursion.

The manner in which the invention deals with the disadvantages of the prior art to provide a low cost infrared vehicle identification system will be evident as the description proceeds.

Summary of the Invention

Accordingly, it is therefore an object of this invention to provide a low cost infrared system that identifies aircraft or other vehicles on airport taxiways and runways.

It is also an object of this invention to provide at an airport a low cost aircraft or vehicle identification system using existing edge light assemblies and associated wiring along runways and taxiways.

It is another object of this invention to provide an infrared vehicle identification system that generates a

graphic display of the airport showing the location of all ground traffic including direction and velocity data and identifies such ground traffic.

The objects are further accomplished by providing a vehicle identification system for identifying aircraft and other vehicles on surface pathways including runways and other areas of an airport comprising means disposed on the aircraft and other vehicles for transmitting identification message data, means disposed in each of a plurality of light assembly means on the airport for receiving and decoding the message data from the transmitting means, means for providing power to each of the plurality of light assembly means, means for processing the decoded identification message data generated by the receiving and decoding means in each of the plurality of light assembly means, means for providing data communication between each of the light assembly means and the processing means, and the processing means comprises means for providing a graphic display of the airport comprising symbols representing the aircraft and other vehicles, each of the symbols having the identification message data displayed. The transmitting means comprises means for creating unique message data which includes aircraft and flight identification, and infrared means coupled to the message creating means for transmitting a coded stream of the message data. The message data further includes position information. The receiving and decoding means comprises an infrared sensor. The receiving and decoding means comprises microprocessor means coupled to the infrared sensor for decoding the message data. The plurality of light assembly means are arranged in two parallel rows along runways and taxiways of the airport. The light assembly means comprises light means coupled to the lines of the power providing means for lighting the airport, vehicle sensing means for detecting aircraft or other vehicles on the airport, microprocessor means coupled to the receiving and decoding means, the light means, the vehicle sensing means and the data communication means for decoding the identification message data, and the data communication means being coupled to the microprocessor means and the lines of the power providing means. The symbols representing aircraft and other vehicles comprise icons having a shape indicating type of aircraft or vehicle. The processing means determines a location of the symbols on the graphic display of the airport in accordance with data received from the light assembly means.

The objects are further accomplished by a vehicle identification system for surveillance and identification of aircraft and other vehicles on an airport comprising a plurality of light circuits on the airport, each of the light circuits comprises a plurality of light assembly means, means for providing power to each of the plurality of light circuits and to each of the light assembly means, means in each of the light assembly means for sensing ground traffic on the airport, means disposed on the aircraft and other vehicles for transmitting identification message data, means disposed in each of the light assembly means for receiving and decoding the message data from the transmitting means, means for processing ground traffic data from the sensing means and decoded message data from each of the light assembly means for presentation on a graphic display of the airport, means for providing data communication between each of the light assembly means and the processing means, the processing means comprises means for providing such graphic display of the airport comprising symbols representing the ground traffic, each of the symbols having direction, velocity and the identification message data displayed. Each of the light circuits are located along the edges of taxiways or runways on the airport. The sensing means comprises infrared detectors. The transmitting means comprises means for creating unique message data which includes aircraft and flight identification, and infrared means coupled to the message creating means for transmitting a coded stream of the message data. The message data further comprises position information. The receiving and decoding means comprises an infrared sensor. The receiving and decoding means comprises microprocessor means coupled to the infrared sensor for decoding the message data. The plurality of light assembly means of the light circuits being arranged in two parallel rows along runways and taxiways of the airport. The light assembly means comprises light means coupled to the lines of the power providing means for lighting the airport, the ground traffic sensing means for detecting aircraft or other vehicles on the airport, microprocessor means coupled to the receiving and decoding means, the light means, the ground traffic sensing means and the data communication means for decoding the identification message data and processing a detection signal from the ground traffic sensing means, and the data communication means being coupled to the microprocessor means and the lines of the power providing means. The light assembly means further comprises a photocell means coupled to the microprocessor means for detecting the light intensity of the light means. The light assembly means further comprises a strobe light coupled to the microprocessor means. The processing means comprises redundant computers for fault tolerance operation. The symbols representing the ground traffic comprise icons having a shape indicating type of aircraft or vehicle. The processing means determines a location of the symbols on the graphic display of the airport in accordance with the data receive from the light assembly means. The processing means determines a future path of the ground traffic based on a ground clearance command, the future path being shown on the graphic display. The processing means further comprises means for predicting an airport incursion. The power providing means comprises constant current power means for providing a separate line to each of the plurality of

light circuits, and network bridge means coupled to the constant current power means for providing a communication channel to the processing means for each line of the constant current power means.

The objects are further accomplished by providing a method of providing a vehicle identification system for identifying aircraft and other vehicles on surface pathways including runways and other areas of an airport comprising the steps of transmitting identification message data with means disposed on the aircraft and other vehicles, receiving and decoding the message data from the transmitting means with means disposed in each of a plurality of light assembly means on the airport, providing power to each of the plurality of light assembly means, processing the decoded identification message data generated by the receiving and decoding means in each of the plurality of light assembly means, providing data communication between each of the light assembly means and the processing means, and providing a graphic display of the airport with the processing means comprising symbols representing the aircraft and other vehicles, each of the symbols having the identification message data displayed. The step of transmitting identification message data comprises the steps of creating unique message data which includes aircraft and flight identification, and transmitting a coded stream of the message data with infrared means coupled to the message creating means. The step of transmitting message data further includes transmitting position information. The step of receiving and decoding the message data includes using an infrared sensor. The step of receiving and decoding the message data further comprises the step of coupling microprocessor means to the infrared sensor for decoding the message data. The step of receiving and decoding the message data with means disposed in the plurality of light assembly means further comprises the step of arranging the plurality of light assembly means in two parallel rows along runways and taxiways of the airport. The step of providing a graphic display comprising symbols representing aircraft and other vehicles further comprises the step of providing icons having a shape indicating type of aircraft or vehicle. The step of providing a graphic display comprises the step of determining a location of the symbols on the graphic display of the airport in accordance with data received from the light assembly means.

Brief Description of the Drawings

Other and further features of the invention will become apparent in connection with the accompanying drawings wherein:

FIG. 1 is a block diagram of an airport vehicle incursion avoidance system;

FIG. 2 is a block diagram of an edge light assembly showing a sensor electronics unit coupled to an edge light of an airfield lighting system;

FIG. 3 is a pictorial diagram of the edge light assembly showing the edge light positioned above the sensor electronics unit;

FIG. 4 is a diagram of an airfield runway or taxiway having a plurality of edge light assemblies positioned along each side of the runway or taxiway for detecting various size aircraft as shown;

FIG. 5 is a block diagram of the central computer system shown in FIG. 1;

FIG. 6 shows eleven network variables used in programming the microprocessor of an edge light assembly to interface with a sensor, a light and a strobe light;

FIG. 7 is a block diagram showing an interconnection of network variables for a plurality of edge light assemblies located on both sides of a runway, each comprising a sensor electronics unit 10 positioned along a taxiway or runway;

FIG. 8 shows a graphic display of a typical taxiway/runway on a portion of an airport as seen by an operator in a control tower, the display showing the location of vehicles as they are detected by the sensors mounted in the edge light assemblies located along taxiways and runways;

FIG. 9 is a block diagram of the data flow within the system shown in FIG. 1 and FIG. 5;

FIG. 10 is a pictorial diagram of an infrared identification system showing an IR transmitter mounted on an airplane wheel strut and an IR receiver mounted in an edge light assembly of an airport lighting system;

FIG. 11 is a block diagram of an IR transmitter of an IR vehicle identification system;

FIG. 12 shows a top view of the IR transmitter mounted on an airplane wheel strut providing a 195° area of coverage generated by an IR light emitting diode array in the IR transmitter;

FIG. 13 shows data fields of a coded data stream transmitted by the IR transmitter;

FIG. 14 is a block diagram of an IR receiver of the IR vehicle identification system;

FIG. 15 is a flow chart of an IR message routine which is a communication protocol continuously performed in an IR receiver microprocessor; and

FIG. 16 is a flow chart of a vehicle sensor routine which is continuously performed in an IR receiver microprocessor.

Description of the Preferred Embodiment

Referring to FIG. 1 a block diagram of an airport vehicle incursion avoidance system 10 is shown comprising a plurality of light circuits 18_{1-n}, each of said light circuits 18_{1-n} comprises a plurality of edge light assemblies 20_{1-n} connected via wiring 21_{1-n} to a lighting vault 16 which is connected to a central computer system 12 via a wide area network 14. Each of the edge light assemblies 20_{1-n} comprises an infrared (IR) detector vehicle sensor 50 (FIG. 2).

The edge light assemblies 20_{1-n} are generally located along side the runways and taxiways of the airport with an average 100 foot spacing and are interconnected to the lighting vault 16 by single conductor series edge light wiring 21_{1-n}. Each of the edge light circuits 18_{1-n} is powered via the wiring 21_{1-n} by a constant current supply 24_{1-n} located in the lighting vault 16.

Referring now to FIG. 1 and FIG. 2, communication between the edge light assemblies 20_{1-n} and the central computer system 12 is accomplished with LON Bridges 22_{1-n} interconnecting the edge light wiring 21_{1-n} with the Wide Area Network 14. Information from a microprocessor 44 located in each edge light assembly 20_{1-n} is coupled to the edge light wiring 21_{1-n} via a power line modem 54. The LON bridges 22_{1-n} transfers message information from the edge light circuits 18_{1-n} via the wiring 21_{1-n} to the wide area network 14. The wide area network 14 provides a transmission path to the central computer system 12. These circuit components also provide the return path communications link from the central computer system 12 to the microprocessor 44 in each edge light assembly 20_{1-n}. Other apparatus and methods, known to one of ordinary skill in the art, for data communication between the edge light assemblies 20_{1-n} and the central computer system 12 may be employed, such as radio techniques, but the present embodiment of providing data communication on the edge light wiring 21_{1-n} provides a low cost system for present airports. The LON Bridge 22 may be embodied by devices manufactured by Echelon Corporation of Palo Alto, California. The wide area network 14 may be implemented by one of ordinary skill in the art using standard Ethernet or Fiber Distributed Data Interface (FDDI) components. The constant current supply 24 may be embodied by devices manufactured by Crouse-Hinds of Winslow, Connecticut.

Referring now to FIG. 2 and FIG. 3, FIG. 3 shows a pictorial diagram of the edge light assembly 20_{1-n}. The edge light assembly 20_{1-n} comprises a bezel including an incandescent lamp 40 and an optional strobe light assembly 48 (FIG. 2) which are mounted above an electronics enclosure 43 comprising a vehicle sensor 50. The electronics enclosure 43 sits on the top of a tubular shaft extending from a base support 56. The light assembly bezel with lamp 40 and base support 56 may be embodied by devices manufactured by Crouse-Hinds of Winslow, Connecticut.

A block diagram of the contents of the electronics enclosure 43 is shown in FIG. 2 which comprises a coupling transformer 53 connected to the edge light wiring 21_{1-n}. The coupling transformer 53 provides power to both the incandescent lamp 40 via the lamp control triac 42 and the microprocessor power supply 52; in addition, the coupling transformer 53 provides a data communication path between the power line modem 54 and the LON Bridges 22_{1-n} via the edge light wiring 21_{1-n}. The microprocessor 44 provides the computational power to run the internal software program that controls the edge light assemblies 20_{1-n}. The microprocessor 44 is powered by the microprocessor power supply 52. Also connected to the microprocessor 44 is the lamp control triac 42, a lamp monitoring photo cell 46, the optional strobe light assembly 48, the vehicle sensor 50, and the data communications modem 54. The microprocessor 44 is used to control the incandescent edge light 40 intensity and optional strobe light assembly 48. The use of the microprocessor 44 in each light assembly 20_{1-n} allows complete addressable control over every light on the field. The microprocessor 44 may be embodied by a VLSI device manufactured by Echelon Corporation of Palo Alto, California 94304, called the Neuron® chip.

Still referring to FIG. 2, the sensor 50 in the present embodiment comprises an infrared (IR) detector and in other embodiments may comprise other devices such as proximity detectors, CCD cameras, microwave motion detectors, inductance loops, or laser beams. The program in the microprocessor 44 is responsible for the initial filtering of the sensor data received from the sensor 50 and responsible for the transmission of such data to the central computer system 12. The sensor 50 must perform the following functions: detect a stationary object, detect a moving object, have a range at least half the width of the runway or taxiway, be low power and be immune to false alarms. This system design does not rely on just one type of sensor. Since sensor fusion functions are performed within the central computer system 12, data inputs from all different types of sensors are acceptable. Each sensor relays a different view of what is happening on the airfield and the central computer system 12 combines them. There are a wide range of sensors that may be used in this system. As a new sensor type becomes available, it can be integrated into this system with a minimum of difficulty. The initial sensor used is an IR proximity detector based around a piezoelectric strip. These are the kind of sensors you use at home to turn on your flood lights when heat and/or movement is detected. When the sensor output pro-

vides an analog signal, an analog-to-digital converter readily known in the art may be used to interface with the microprocessor 44.

Another proximity detector that can be used is based around a microwave Gunn diode oscillator. These are currently in use in such applications as Intrusion Alarms, Door Openers, Distance Measurement, Collision Warning, Railroad Switching, etc. These types of sensors have a drawback because they are not passive devices and care needs to be taken to select frequencies that would not interfere with other airport equipment. Finally, in locations such as the hold position lines on taxiways, solid state laser and detector combinations could be used between adjacent taxiway lights. These sensor systems create a beam that when broken would identify the location of the front wheel of the airplane. This type of detector would be used in those locations where the absolute position of a vehicle was needed. The laser beam would be modulated by the microprocessor 44 to avoid the detector being fooled by any other stray radiation.

Referring to FIG. 2 and FIG. 4, a portion of an airport runway 64 or taxiway is shown having a plurality of edge light assemblies 20_{1-8} positioned along each side of the runway or taxiway for detecting various size airplanes or vehicles 60, 62. The dashed lines represent the coverage area of the sensors 50 located in each edge light assembly 20_{1-8} positioned along each side of the runway 64 or taxiway to insure detection of any airplane 60, 62 or other vehicles traveling on such runway 64 or taxiway. The edge light assemblies 20_{1-n} comprising the sensor 50 are logically connected together in such a way that an entire airport is sensitized to the movement of vehicles. Node to node communication takes place to verify and identify the location of the vehicles. Once this is done a message is sent to the central computer system 12 reporting the vehicles location. Edge lights assemblies (without a sensor electronics unit 43) and taxiway power wiring currently exist along taxiways, runways and open areas of airports, therefore, the sensor electronics unit 43 is readily added to existing edge lights and existing taxiway power wiring without the inconvenience and expense of closing down runways and taxiways while installing new cabling.

Referring now to FIG. 1, FIG. 5, FIG. 8 and FIG. 9, the central computer system 12 is generally located at a control tower or terminal area of an airport and is interconnected to the LON Bridges 22_{1-n} located in the lighting vault 16 with a Wide Area Network 14. The central computer system 12 comprises two redundant computers, computer #1 26 and computer #2 28 for fault tolerance, the display 30, speech synthesis units 29 & 31, alert lights 34, keyboard 27 and a speech recognition unit 33, all of these elements being interconnected by the wide area network 14 for the transfer of information. The two computers 26 and 28 communicate with the microprocessors 44 located in the edge light assemblies 20_{1-n}. Data received from the edge light assembly 20_{1-n} microprocessors 44 are used as an input to a sensor fusion software module 101 (FIG. 9) run on the redundant computers 26 and 28. The output of the sensor fusion software module 101 operating in the computers 26, 28 is used to drive the CRT display 30 which displays the location of each vehicle on the airport taxiway and runways as shown in FIG. 8. The central computer system 12 may be embodied by devices manufactured by IBM Corporation of White Plains, New York. The Wide Area Network 14 may be embodied by devices manufactured by 3Com Corporation of Santa Clara, California. The speech synthesis units 29, 31 and the speech recognition unit 33 may be embodied by devices manufactured by BBN of Cambridge, Massachusetts.

The speech synthesis unit 29 is coupled to a speaker 32. Limited information is sent to the speech synthesis unit 29 via the wide area network 14 to provide the capability to give an air traffic controller a verbal alert. The speech synthesis unit 31 is coupled to a radio 37 having an antenna 39 to provide the capability to give the pilots a verbal alert. The voice commands from the air traffic controller to the pilots are captured by microphone 35 and sent to the pilots via radio 36 and antenna 38. In the present embodiment a tap is made and the speech information is sent to both the radio 36 and the speech recognition unit 33 which is programmed to recognize the limited air traffic control vocabulary used by a controller. This includes airline names, aircraft type, the numbers 0-9, the name of the taxiways and runways and various short phrases such as "hold short", "expedite" and "give way to." The output of the speech recognition unit 33 is fed to the computers 26, 28.

Referring again to FIG. 2, the power line modem 54 provides a data communication path over the edge light wiring 21_{1-n} for the microprocessor 44. This two way path is used for the passing of command and control information between the various edge light assemblies 20_{1-n} and the central computer system 12. A power line transceiver module in the power line modem 54 is used to provide a data channel. These modules use carrier current approach to create the data channel. Power line modems that operate at carrier frequencies in the 100 to 450 Khz band are available from many manufacturers. These modems provide digital communication paths at data rates of up to 10,000 bits per second utilizing direct sequence spread spectrum modulation. They conform to FCC power line carrier requirements for conducted emissions, and can work with up to 55 dB of power line attenuation. The power line modem 54 may be embodied by a device manufactured by Echelon Corporation of Palo Alto, California 94304, called the PLT-10 Power Line Transceiver Module.

The data channel provides a transport layer or lowest layer of the open system interconnection (OSI) protocol used in the data network. The Neuron® chip which implements the microprocessor 44 contains all of the firmware required to implement a 7 layer OSI protocol. When interconnected via an appropriate medium the Neuron® chips automatically communicate with one another using a robust Collision Sense Multiple Access (CSMA) protocol with forward error corrections, error checking and automatic retransmission of missed messages (ARQ).

The command and control information is placed in data packets and sent over the network in accordance with the 7 Layer OSI protocol. All messages generated by the microprocessor 44 and destined for the central computer system 12 are received by the network bridge 22 via the power lines 21_{1-n} and routed to the central computer system 12 over the wide area network 14.

The Neuron® chip of the microprocessor 44 comprises three processors (not shown) and the firmware required to support a full 6 layer open systems interconnection (OSI) protocol. The user is allocated one of the processors for the application code. The other two processors give the application program access to all of the other Neuron® chips in the network. This access creates a Local Operating Network or LON. A LON can be thought of as a high level local area network LAN. The use of the Neuron® chip for the implementation of this invention, reduces the amount of custom hardware and software that otherwise would have to be developed.

Data from the sensor electronic unit 43 of the edge light assemblies 20_{1-n} is coupled to the central computer system 12 via the existing airport taxiway lighting power wiring 21. Using the existing edge light power line to transfer the sensor data into a LON network has many advantages. As previously pointed out, the reuse of the existing edge lights eliminates the inconvenience and expense of closing down runways and taxiways while running new cable and provides for a low cost system.

The Neuron® chip allows the edge light assemblies 20_{1-n} to automatically communicate with each other at the applications level. This is accomplished through network variables which allow individual Neuron® chips to pass data between themselves. Each Neuron® 'C' program comprises both local and network variables. The local variables are used by the Neuron® program as a scratch pad memory. The network variables are used by the Neuron® program in one of two ways, either as a network output variables or a network input variables. Both kinds of variables can be initialized, evaluated and modified locally. The difference comes into play in that once a network output variable is modified, network messages are automatically sent to each network input variable that is linked to that output variable. This variable linking is done at installation time. As soon as a new value of a network input variable is received by a Neuron® chip, the code is vectored off to take appropriate action based upon the value of the network input variable. The advantage to the program is that this message passing scheme is entirely transparent since the message passing code is part of the embedded Neuron® operating system.

Referring now to FIG. 6, eleven network variables have been identified for a sensor program in each microprocessor 44 of the edge light assemblies 20_{1-n}. The sensor 50 function has two output variables: prelim_detect 70 and confirmed_detect 72. The idea here is to have one output trigger whenever the sensor 50 detects movement. The other output does not trigger unless the local sensor and the sensor on the edge light across the runway both spot movement. Only when the detection is confirmed will the signal be fed back to the central computer system 12. This technique of confirmation helps to reduce false alarms in order to implement this technique the adjacent sensor 50 has an input variable called adj_prelim_detect 78 that is used to receive the other sensors prelim_detect output 70. Other input variables are upstream_detect 74 and downstream_detect 76 which are used when chaining adjacent sensors together. Also needed is a detector_sensitivity 80 input that is used by the central computer system 12 to control the detection ability of the sensor 50.

The incandescent light 40 requires two network variables, one input and the other an output variable. The input variable light_level 84 would be used to control the light's brightness. The range would be OFF or 0% all the way to FULL ON or 100%. This range from 0% to 100% would be made in 0.5% steps. Since the edge light assembly 20_{1-n} also contains the photocell 46, an output variable light_failure 84 is created to signal that the lamp did not obtain the desired brightness.

The strobe light 48 requires three input variables. The strobe-mode 86 variable is used to select either the OFF, SEQUENTIAL, or ALTERNATE flash modes. Since the two flash modes require a distinct pattern to be created, two input variables active_delay 88 and flash_delay 90 are used to time align the strobe flashes. By setting these individual delay factors and then addressing the Neuron® chips as a group, allows the creation of a field strobe pattern with just one command.

Referring now to FIG. 7, a block diagram of an interconnection of network variables for a plurality of edge light assemblies 20_{1-n} located on both sides of a runway is shown, each of the edge light assemblies 20_{1-n} comprising a microprocessor 44. Each Neuron® program in the microprocessor 44 is designed with certain network input and output variables. The user writes the code for the Neuron® chips in the microprocessor 44

assuming that the inputs are supplied and that the outputs are used. To create an actual network the user has to "wire up" the network by interconnecting the individual nodes with a software linker. The resulting distributed process is best shown in schematic form, and a portion of the network interconnect matrix is shown in Figure 7. The prelim_detect 70 output of a sensor node 44_1 is connected to the adj_primary_detect 92 input of the sensor node 44_4 across the taxiway. This is used as a means to verify actual detections and eliminate false reports. The communications link between these two nodes 44_1 and 44_4 is part of the distributed processing. The two nodes communicate among themselves without involving the central computer system 12. If in the automatic mode or if instructed by the controller, the system will also alert the pilots via audio and visual indications.

Referring again to FIG. 1 and FIG. 4, the central computer system 12 tracks the movement of vehicles as they pass from the sensor 50 to sensor 50 in each edge light assembly 20_{1-n}. Using a variation of a radar automatic track algorithm, the system can track position, velocity and heading of all aircraft or vehicles based upon the sensor 50 readings. New vehicles are entered into the system either upon leaving a boarding gate or landing. Unknown vehicles are also tracked automatically. Since taxiway and runway lights are normally across from each other on the pavement (as shown in FIG. 4 and FIG. 7), the microprocessor 44 in each edge lights assembly 20_{1-n} is programmed to combine their sensor 50 inputs and agree before reporting a contact. A further refinement is to have the microprocessor 44 check with the edge light assemblies 20_{1-n} on either side of them to see if their sensors 50 had detected the vehicle. This allows a vehicle to be handed off from sensor electronic unit 43 to sensor electronic unit 43 of each edge light assembly 20_{1-n} as it travels down the taxiway. This also assures that vehicle position reports remain consistent. Vehicle velocity may also be calculated by using the distance between sensors, the sensor pattern and the time between detections.

Referring to FIG. 5 and FIG. 8, the display 30 is a color monitor which provides a graphical display of the airport, a portion of which is shown in FIG. 8. This is accomplished by storing a map of the airport in the redundant computers 26 and 28 in a digital format. The display 30 shows the location of airplanes or vehicles as they are detected by the sensors 50 mounted in the edge light assemblies 20_{1-n} along each taxiway and runway or other airport surface areas. All aircraft or vehicles on the airport surface are displayed as icons, with the shape of the icons being determined by the vehicle type. Vehicle position is shown by the location of the icon on the screen. Vehicle direction is shown by either the orientation of the icon or by an arrow emanating from the icon. Vehicle status is conveyed by the color of the icon. The future path of the vehicle as provided by the ground clearance command entered via the controllers microphone 35 is shown as a colored line on the display 30. The status of all field lights including each edge light 20_{1-n} in each edge light circuit 18_{1-n} is shown via color on the display 30.

Use of object orientated software provides the basis for building a model of an airport. The automatic inheritance feature allows a data structure to be defined once for each object and then replicated automatically for each instance of that object. Automatic flow down assures that elements of the data base are not corrupted due to typing errors. It also assures that the code is regular and structured. Rule based object oriented programming makes it difficult to create unintelligible "spaghetti code." Object oriented programming allows the runways, taxiways, aircraft and sensors, to be decoded directly as objects. Each of these objects contains attributes. Some of these attributes are fixed like runway 22R or flight UA347, and some are variable like vehicle status and position.

In conventional programming we describe the attributes of an object in data structures and then describe the behaviors of the object as procedures that operate on those data structures. Object oriented programming shifts the emphasis and focuses first on the data structure and only secondarily on the procedures. More importantly, object oriented programming allows us to analyze and design programs in a natural manner. We can think in terms of runways and aircraft instead of focusing on either the behavior or the data structures of the runways and aircraft.

Table 1 shows a list of objects with corresponding attributes. Each physical object that is important to the runway incursion problem is modeled. The basic airplane or vehicle tracking algorithm is shown in Table 2 in a Program Design Language (PDL). The algorithm which handles sensor fusion, incursion avoidance and safety alerts is shown in a single program even though it is implemented as distributed system using both the central computer system 12 and the sensor microprocessors 44.

TABLE 1

OBJECT	ATTRIBUTE	DESCRIPTION
Sensor	Location	X & Y coordinates of sensor
	Circuit	AC wiring circuit name & number
	Unique_address	Net address for this sensor and its mate
	Lamp_intensity	0% to 100% in 0.5% steps
	Strobe_status	Blink rate/off
	Strobe-delay	From start signal
	Sensor_status	Detect/no detect
	Sensor_type	IR, laser, proximity, etc.
Runway	Name	22R, 27, 33L, etc.
	Location	X & Y coordinates of start of center line
	Length	In feet
	Width	In feet
	Direction	In degrees from north
	Status	Not_active, active_takeoff, active_landing, alarm
	Sensors (MV)	List of lights/sensors along this runway
	Intersections (MV)	List of intersections
	Vehicles	List of vehicles on the runway
Taxiway	Name	Name of taxiway
	Location	X & Y coordinates of start of center line
	Length	In feet
	Width	In feet
	Direction	In degrees from north
	Status	Not active, active, alarm
	Sensors (MV)	List of intersections
	Hold_Locations	List of holding locations
	Vehicles (MV)	List of vehicles on the runway

Intersection	Name	Intersection Name
	Location	Intersection of two center lines
	Status	Vacant/Occupied
	Sensors (MV)	List of sensors creating intersection border
Aircraft	Airline	United
	Model	727-200
	Tail-number	N32742
	Empty_weight	9.5 tons
	Freight_weight	2.3 tons
	Fuel_weight	3.2 tons
	Top_speed	598 mph
	V1_speed	100 mph
	V2_speed	140 mph
	Acceleration	0.23 g's
	Deceleration	0.34 g's

MV = Multi-variable or array

Table 2

```
while (forever)
| if (edge light shows a detection)
| | if (adjacent light also shows a detection sensor fusion)
| | | /* CONFIRMED DETECTION */
| | | if (previous block showed a detection)
| | | | /* ACCEPT HANDOFF */
| | | | Update aircraft position and speed
| | | else
| | | | /* MAY BE AN ANIMAL OR SERVICE TRUCK */
| | | | Alert operator to possible incursion
| | | | /* MAY BE AN AIRCRAFT ENTERING THE SYSTEM */
| | | | Start a new track
| | else
| | | Request status from adjacent light
```

```
|  |  |  if (Adjacent light is OK)
|  |  |  |  /* NON CONFIRMED DETECTION */
|  |  |  else
|  |  |  |  Flag adjacent light for repair
|  |  |  endif
|  |  endif
|  endif
|  if (Edge light loses a detection AND status is OK)
|  |  if (Next block showed a detection)
|  |  |     /* PROPER HANDOFF */
|  |  else
|  |  |  if (vehicle speed > = takeoff)
|  |  |  |  Handoff to departure control
|  |  |  else
|  |  |  |  /* MISSING HANDOFF */
|  |  |  |  Alert operator to possible incursion
|  |  |  endif
|  |  endif
|  endif
|  /* CHECK FOR POSSIBLE COLLISIONS */
|  for (all tracked aircraft)
|  |  Plot future position
|  |  if (position conflict)
|  |  |     Alert operator to possible incursion
|  |  endif
|  endif
|  Update display
endwhile
```

Referring again to FIG. 1 and FIG. 2, the control of taxiway lighting intensity is usually done by placing all the lights on the same series circuit and then regulating the current in that circuit. In the present embodiment the intensity of the lamp 40 is controlled by sending a message with the light intensity value to the microprocessor 44 located within the light assembly 20_{1-n}. The message allows for intensity settings in the range of 0 to 100% in 0.5% steps. The use of photocell 46 to check the light output allows a return message to be sent if the bulb does not respond. This in turn generates a maintenance report on the light. The strobe light 48 provides an additional optional capability under program control of the microprocessor 44. Each of the microprocessors 44 in the edge light assemblies 20 is individually addressable. This means every lamp on the field is controlled individually by the central computer system 12.

The system 10 can be programmed to provide an Active Runway Indicator by using the strobe lights 48 in those edge light assemblies 20_{1-n} located on the runway 64 to continue the approach light "rabbit" strobe

pattern all the way down the runway. This lighting pattern could be turned-on as a plane is cleared for landing and then turned-off after the aircraft has touched down. A pilot approaching the runway along an intersecting taxiway would be alerted in a clear and unambiguous way that the runway was active and should not be crossed.

If an incursion was detected the main computers 26, 28 could switch the runway strobe lights 48 from the "rabbit" pattern to a pattern that alternatively flashes either side of the runway in a wig-wag fashion. A switch to this pattern would be interpreted by the pilot of an arriving aircraft as a wave off and a signal to go around. The abrupt switch in the pattern of the strobes would be instantaneously picked up by the air crew in time for them to initiate an aborted landing procedure.

During Category III weather conditions both runway and taxiway visibility are very low. Currently radio based landing systems are used to get the aircraft from final approach to the runway. Once on the runway it is not always obvious which taxiways are to be used to reach the airport terminal. In system 10 the main computers 26,28 can control the taxiway lamps 40 as the means for guiding aircraft on the ground during CAT III conditions. Since the intensity of the taxiway lamps 40 can be controlled remotely, the lamps just in front of an aircraft could be intensified or flashed as a means of guiding it to the terminal.

Alternatively, a short sequence of the "rabbit" pattern may be programmed into the taxiway strobes just in front of the aircraft. At intersections, either the unwanted paths may have their lamps turned off or the entrance to the proper section of taxiway may flash directing the pilot to head in that direction. Of course in a smart system only those lights directly in front of a plane would be controlled, all other lamps on the field would remain in their normal mode.

Referring now to FIG. 9, a block diagram is shown of the data flow within the system 10 (as shown in FIG. 1 and FIG. 5). The software modules are shown that are used to process the data within the computers 26, 28 of the central computer system 12. The tracking of aircraft and other vehicles on the airport operates under the control of a sensor fusion software module 101 which resides in the computers 26, 28. The sensor fusion software module 101 receives data from the plurality of sensors 50, a sensor 50 being located in each edge light assembly 20_{1-n} which reports the heat level detected, and this software module 101 combines this information through the use of rule based artificial intelligence to create a complete picture of all ground traffic at the airport on a display 30 of the central computer system 12.

The tracking algorithm starts a track upon the first report of a sensor 50 detecting a heat level that is above the ambient background level of radiation. This detection is then verified by checking the heat level reported by the sensor directly across the pavement from the first reporting sensor. This secondary reading is used to confirm the vehicle detected and to eliminate false alarms. After a vehicle has been confirmed the sensors adjacent to the first reporting sensor are queried for changes in their detected heat level. As soon as one of the adjacent sensors detects a rise in heat level a direction vector for the vehicle can be established. This process continues as the vehicle is handed off from sensor to sensor in a bucket brigade fashion as shown in FIG. 7. Vehicle speed can be roughly determined by calculating the time between vehicle detection by adjacent sensors. This information is combined with information from a system data base on the location of each sensor to calculate the velocity of the target. Due to hot exhaust or jet blast, the sensors behind the vehicle may not return to a background level immediately. Because of these condition, the algorithm only uses the first four sensors (two on either side of the taxiway) to calculate the vehicles position. The vehicle is always assumed to be on the centerline of the pavement and between the first four reporting sensors.

Vehicle identification can be added to the track either manually or automatically by an automated source that can identify a vehicle by its position. An example would be prior knowledge of the next aircraft to land on a particular runway. Tracks are ended when a vehicle leaves the detection system. This can occur in one of two ways. The first way is that the vehicle leaves the area covered by the sensors 50. This is determined by a vehicle track moving in the direction of a gateway sensor and then a lack of detection after the gateway sensor has lost contact. A second way to leave the detection system is for a track to be lost in the middle of a sensor array. This can occur when an aircraft departs or a vehicle runs onto the grass. Takeoff scenarios can be determined by calculating the speed of the vehicle just before detection was lost. If the vehicle speed was increasing and above rotation speed then the aircraft is assumed to have taken off. If not then the vehicle is assumed to have gone on to the grass and an alarm is sounded.

Referring to FIG. 5 and FIG. 9, the ground clearance routing function is performed by the speech recognition unit 33 along with the ground clearance compliance verifier software module 103 running on the computers 26,28. This software module 103 comprises a vehicle identification routine, clearance path routing, clearance checking routine and a path checking routine.

The vehicle identification routine is used to receive the airline name and flight number (i.e. "Delta 374") from the speech recognition unit 33 and it highlights the icon of that aircraft on the graphic display of the airport on display 30.

The clearance path routine takes the remainder of the controller's phrase (i.e. "outer taxiway to echo, hold short of runway 15 Left") and provides a graphical display of the clearance on the display 30 showing the airport.

The clearance checking routine checks the clearance path for possible conflict with other clearances and vehicles. If a conflict is found the portion of the path that would cause an incursion is highlighted in a blinking red and an audible indication is given to the controller via speaker 32.

The path checking routine checks the actual path of the vehicle as detected by the sensors 50 after the clearance path has been entered into the computers 26, 28 and it monitors the actual path for any deviation. If this routine detects that a vehicle has strayed from the assigned course, the vehicle icon on the graphic display of the airport flashes and an audible indicator is given to the controller via speaker 32 and optionally the vehicle operator via radio 37.

The airport vehicle incursion avoidance system 10 operates under the control of safety logic routines which reside in the collision detection software module 104 running on computers 26, 28. The safety logic routines receive data from the sensor fusion software module 101 location program via the tracker software module 102 and interpret this information through the use of rule based artificial intelligence to predict possible collisions or runway incursions. This information is then used by the central computer system 12 to alert tower controllers, aircraft pilots and truck operators to the possibility of a runway incursion. The tower controllers are alerted by the display 30 along with a computer synthesized voice message via speaker 32. Ground traffic is alerted by a combination of traffic lights, flashing lights, stop bars and other alert lights 34, lamps 40 and 48, and computer generated voice commands broadcast via radio 36.

Knowledge based problems are also called fuzzy problems and their solutions depend upon both program logic and an interface engine that can dynamically create a decision tree, selecting which heuristics are most appropriate for the specific case being considered. Rule based systems broaden the scope of possible applications. They allow designers to incorporate judgement and experience, and to take a consistent solution approach across an entire problem set.

The programming of the rule based incursion detections software is very straight forward. The rules are written in English allowing the experts, in this case the tower personnel and the pilots, to review the system at an understandable level. Another feature of the rule based system is that the rules stand alone. They can be added, deleted or modified without affecting the rest of the code. This is almost impossible to do with code that is created from scratch. An example of a rule we might use is:

```
If (Runway_Status = Active)
    then (Stop_Bar_Lights = RED).
```

This is a very simple and straight forward rule. It stands alone requiring no extra knowledge except how Runway_Status is created. So let's make some rules affecting Runway_Status.

```
If (Departure = APPROVED) or (Landing = IMMINENT),
    then (Runway_Status = ACTIVE).
```

For incursion detection, another rule is:

```
If (Runway_Status = ACTIVE) and (Intersection = OCCUPIED),
    then (Runway_Incursion = TRUE).
```

Next, detect that an intersection of a runway and taxiway are occupied by the rules:

```
If (Intersection_Sensors = DETECT),
    then (Intersection = OCCUPIED).
```

To predict that an aircraft will run a Hold Position stop, the following rule is created:

```
If (Aircraft_Stopping_Distance > Distance_to_Hold_Position),
    then (Intersection = OCCUPIED).
```

In order to show that rules can be added without affecting the reset of the program, assume that after a demonstration of the system 10 to tower controllers, they decided that they wanted a "Panic Button" in the tower to override the rule based software in case they spot a safety violation on the ground. Besides installing the button, the only other change would be to add this extra rule.

```
If (Panic_button = PRESSED),
    then (Runway_Incursion = TRUE).
```

It is readily seen that the central rule based computer program is very straight forward to create, understand and modify. As types of incursions are defined, the system 10 can be upgraded by adding more rules.

Referring again to FIG. 9, the block diagram shows the data flow between the functional elements within the system 10 (FIG. 1). Vehicles are detected by the sensor 50 in each of the edge light assemblies 20_{1-n}. This information is passed over the local operating network (LON) via edge light wiring 21_{1-n} to the LON bridges 22_{1-n}. The individual message packets are then passed to the redundant computers 26 and 28 over the wide area network (WAN) 14 to the WAN interface 108. After arriving at the redundant computers 26 and 28, the message packet is checked and verified by a message parser software module 100. The contents of the mes-

sage are then sent to the sensor fusion software module 101. The sensor fusion software module 101 is used to keep track of the status of all the sensors 50 on the airport; it filters and verifies the data from the airport and stores a representative picture of the sensor array in a memory. This information is used directly by the display 30 to show which sensors 50 are responding and used by the tracker software module 102. The tracker software module 102 uses the sensor status information to determine which sensor 50 reports correspond to actual vehicles. In addition, as the sensor reports and status change, the tracker software module 102 identifies movement of the vehicles and produces a target location and direction output. This information is used by the display 30 in order to display the appropriate vehicle icon on the screen.

The location and direction of the vehicle is also used by the collision detection software module 104. This module checks all of the vehicles on the ground and plots their expected course. If any two targets are on intersecting paths, this software module generates operator alerts by using the display 30, the alert lights 34, the speech synthesis unit 29 coupled to the associated speaker 32, and the speech synthesis unit 31 coupled to radio 37 which is coupled to antenna 39.

Still referring to FIG. 9, another user of target location and position data is the ground clearance compliance verifier software module 103. This software module 103 receives the ground clearance commands from the controller's microphone 35 via the speech recognition unit 33. Once the cleared route has been determined, it is stored in the ground clearance compliance verifier software module 103 and used for comparison to the actual route taken by the vehicle. If the information received from the tracker software module 102 shows that the vehicle has deviated from its assigned course, this software module 103 generates operator alerts by using the display 30, the alert lights 34, the speech synthesis unit 29 coupled to speaker 32, and the speech synthesis unit 31 coupled to radio 37 which is coupled to antenna 39.

The keyboard 27 is connected to a keyboard parser software module 109. When a command has been verified by the keyboard parser software module 109, it is used to change display 30 options and to reconfigure the sensors and network parameters. A network configuration data base 106 is updated with these reconfiguration commands. This information is then turned into LON message packets by the command message generator 107 and sent to the edge light assemblies 20_{1-n} via the WAN interface 108 and the LON bridges 22_{1-n}.

Referring now to FIG. 1 and FIG. 10, FIG. 10 shows a pictorial diagram of an infrared vehicle identification system 109 invention comprising an infrared (IR) transmitter 112 mounted on an airplane 110 wheel strut 111 and an IR receiver 128 which comprises a plurality of edge light assemblies 20_{1-n} of an airport lighting system also shown in FIG. 1. The combination of the IR transmitter 112 mounted on aircraft and/or other vehicles and a plurality of IR receivers 128 located along runways and taxiways form the infrared vehicle identification system 109 for use at airports for the safety, guidance and control of surface vehicles in order to provide positive detection and identification of all aircraft and other vehicles and to prevent runway incursions. Runway incursions generally occur when aircraft or other vehicles get onto a runway and conflict with aircraft cleared to land or takeoff on that same runway. All such incursions are caused by human error.

Referring now to FIG. 11, a block diagram of the IR transmitter 112 is shown comprising an embedded microprocessor 118 having DC power 114 inputs from the aircraft host or vehicle on which the IR transmitter 112 is mounted and an ID switch 116 within the aircraft for entering vehicle identification data which is received by the IR transmitter 112 on a serial line. Vehicle position information is provided to the IR transmitter 112 from a vehicle position receiver 117 which may be embodied by a global positioning system (GPS) receiver readily known in the art. The output of embedded microprocessor 118 feeds an IR emitter comprising a light emitting diode (LED) array 120. When power is applied to the IR transmitter 112, the microprocessor continuously outputs a coded data stream 121 (FIG. 13) which is transmitted by the IR LED array 120. The embedded microprocessor 118 may be embodied by microprocessor Model MC 6803 or equivalent manufactured by Motorola Microprocessor Products of Austin; Texas. The IR LED array 120 may be embodied by IR LED Devices manufactured by Harris Semiconductor of Melborne, Florida.

Referring now to FIG. 12, a top view of the IR transmitter 112 comprising the IR LED array 120 mounted on an airplane wheel strut 111 is shown. The IR LED array 120 comprises a plurality of high power LEDs each having a beam width of 15°. By placing thirteen LEDs in an array, a 195° area can be covered. The IR LED array 120 illuminates edge light assemblies 20_{1-4} along the edges of the runway 64. Each of the edge light assemblies 20_{1-4} comprises an IR receiver 128.

Referring now to FIG. 13, the coded data stream emitted from the IR transmitter 112 comprises six separate fields. The first field is called timing pattern 122 and comprises a set of equally spaced pulses. The second field is called unique word 123 which marks the beginning of a message. The third field is called character count 124 which specifies the number of characters in a message. The fourth field is called vehicle identification number 125. The fifth field is called vehicle position 126 and provides latitude and longitude information.

The sixth field is called message checksum 127. The equally spaced pulses of the timing pattern 122 allow the IR receiver 128 to calculate the baud rate of a transmitted message and automatically adjust its internal timing to compensate for either a doppler shift or an offset in clock frequency. The checksum 126 field allows the IR receiver 128 to find the byte boundary. The character count 124 field is used to alert the IR receiver 128 in the edge light assemblies 20_{1-4} as to the length of the message being received. The IR receiver 128 uses this field to determine when the message has ended and if the message was truncated.

The vehicle identification number 125 field comprises an airline flight number or a tail number of an aircraft or a license number of other vehicles. The actual number can be alpha-numeric since each character will be allocated eight (8) bits. An ASCII code which is known to those of ordinary skill in the art is an example of a code type that may be used. The only constraints on the vehicle ID number is that it be unique to the vehicle and that it be entered in the airport's central computer data base to facilitate automatic identification. The checksum 127 guarantees that a complete and correct message is received. If the message is interrupted for any reason, such as a blocked beam or a change in vehicle direction, it is instantly detected and the reception voided. This procedure reduces the number of false detects and guarantees that only perfect vehicle identification messages are passed on to the central computer system 12 at the airport tower.

Referring now to FIG.1, FIG. 2, FIG. 10 and FIG. 14, a block diagram of the IR receiver 128 is shown in FIG. 14 which comprises and IR sensor 130 connected to an edge light assembly 20_{1-n} shown in FIG. 1, FIG. 2 and FIG. 10, on an airport. In FIG. 14, only the relevant portions of FIG. 2 are shown, but it should be understood that all of the elements of the edge light assembly 20_{1-n} shown in FIG. 2 are considered present in FIG. 14. The IR receiver 128 comprises the IR sensor 130 which receives the coded data stream 121 (FIG. 13) from the transmitter 112. The output of the IR sensor 130 is fed to the microprocessor 44 for processing by an IR message routine 136 for detecting the data message. A vehicle sensor routine 138 in microprocessor 44 processes signals from the vehicle sensor 50 for detecting an aircraft or other vehicles. The IR message routine 136 is implemented with software within the microprocessor 44 as shown in the flow chart of FIG. 15. The vehicle sensor routine 138 is also implemented with software within the microprocessor 44 as shown in the flow chart of FIG. 16. The outputs of the IR message routine 136 and vehicle sensor routine 138 are processed by the microprocessor 44 which sends via the power line modem 54 the identified aircraft or vehicle and their position data over the edge light wiring 21_{1-n} communication lines to the central computer system 12 shown in FIG. 1 at the airport terminal or control tower. The IR sensor 130 may be embodied with Model RY5BD01 IR sensor manufactured by Sharp Electronics, of Paramus, New Jersey. The microprocessor 44 may be embodied by the VLSI Neuron® Chip, manufactured by Echelon Corporation, of Palo Alto, California.

Referring to FIG. 15, a flow chart of the IR message routine 136 is shown which is a communication protocol continuously performed in the microprocessor 44 of the IR receiver 128. After an IR signal is detected 150 the next action is transmitter acquisition or to acquire timing 152. The microprocessor 44 looks for the proper timing relationship between the received IR pulses. If the correct on/off ratio exists, the microprocessor 44 calculates the baud rate from the received timing and waits to acquire the unique word 156 signifying byte boundary and then checks for the capture of the character count 160 field byte. After the character count is known, the microprocessor 44 then captures each character in the vehicle ID 162 field and stores them away in a buffer. It then captures vehicle position 163 including latitude and longitude data. If the IR coded data stream is disrupted before all the vehicle ID characters are received, the microprocessor 44 aborts this reception try and returns to the acquisition or IR detected 150 state. After all characters have been received, the checksum 164 is calculated. If the checksum matches 166, then the message is validated and the vehicle ID relayed 168 to the central computer system 12. With this scheme the microprocessor 44 is implementing both the physical and a link layer of the OSI protocol by providing an error free channel.

Referring now to FIG. 16, a flow chart is shown of the vehicle sensor routine 138 software running on microprocessor 44. This software routine 138 runs as a continuous loop. An internal timer is continuously checked for a time out condition (timer = zero 170). As soon as the timer expires the analog value from sensor 50 is read (Read Sensor Value 171) by the microprocessor 44 and the timer is reset to the poll_time 172 variable downloaded by the central computer system 12. This sensor value is compared against a predetermined detection threshold 173 and downloaded by the central computer system 12. If the sensor value is less than the detection threshold, the microprocessor 44 sets the network variable prelim_detect to the FALSE state 174. If the sensor value is greater than the detection threshold the microprocessor 44 sets the network variable prelim_detect to the TRUE state 175. If a preliminary detection is declared, the program then checks to see what reporting mode 176 is in use. If all detections are required to be sent to the central computer system 12, then this sensor value 180 is sent. If only those readings that are different from the previous reading by a predetermined delta and download by the central computer system 12, then this check is made 177. If the change is greater than the delta 177, the program checks to see if it should confirm the detection 178 to eliminate any

false alarms. If a confirmation is not required, then this sensor value 181 is sent. If in the confirmation mode, then the adjacent sensor's 179 preliminary network variable is checked. If the adjacent sensor has also detected the object, then the current sensor value 182 is sent.

This concludes the description of the preferred embodiment. However, many modifications and alterations will be obvious to one of ordinary skill in the art without departing from the spirit and scope of the inventive concept. Therefore, it is intended that the scope of this invention be limited only by the appended claims.

Claims

1. A vehicle identification system for identifying aircraft and other vehicles on surface pathways including runways and other areas of an airport comprising:
   means disposed on said aircraft and other vehicles for transmitting identification message data;
   means disposed in each of a plurality of light assembly means on said airport for receiving and decoding said message data from said transmitting means;
   means for providing power to each of said plurality of light assembly means;
   means for processing said decoded identification message data generated by said receiving and decoding means in each of said plurality of light assembly means;
   means for providing data communication between each of said light assembly means and said processing means; and
   said processing means comprises means for providing a graphic display of said airport comprising symbols representing said aircraft and other vehicles, each of said symbols having said identification message data displayed.

2. The vehicle identification system as recited in Claim 1 wherein said transmitting means comprises:
   means for creating a unique message data which includes aircraft and flight identification; and
   infrared means coupled to said message creating means for transmitting a coded stream of said message data.

3. The vehicle identification system as recited in Claim 3 wherein:
   said message data further includes position information.

4. The vehicle identification system as recited in Claim 1 wherein:
   said receiving and decoding means comprises an infrared sensor.

5. The vehicle identification system as recited in Claim 3 wherein:
   said receiving and decoding means comprises microprocessor means coupled to said infrared sensor for decoding said message data.

6. The vehicle identification system as recited in Claim 1 wherein:
   said plurality of light assembly means being arranged in two parallel rows along runways and taxiways of said airport.

7. The vehicle identification system as recited in Claim 1 wherein said light assembly means comprises:
   light means coupled to said lines of said power providing means for lighting said airport;
   vehicle sensing means for detecting aircraft or other vehicles on said airport;
   microprocessor means coupled to said receiving and decoding means, said light means, said vehicle sensing means and said data communication means for decoding said identification message data; and
   said data communication means being coupled to said microprocessor means and said lines of said power providing means.

8. The vehicle identification system as recited in Claim 1 wherein:
   said symbols representing aircraft and other vehicles comprise icons having a shape indicating type of aircraft or vehicle.

9. The vehicle identification system as recited in Claim 1 wherein:
   said processing means determines a location of said symbols on said graphic display of said airport in accordance with data received from said light assembly means.

10. A vehicle identification system for identifying aircraft and other vehicles on surface pathways including runways and other areas of an airport comprising:

means disposed on said aircraft and other vehicles for creating a unique message including aircraft and flight identification;

infrared means coupled to said message creating means for transmitting a coded stream of said message data;

infrared means disposed in each of a plurality of light assembly means on said airport for receiving said message data from said transmitting means;

microprocessor means coupled to said receiving means for decoding said message data;

means for providing power to each of said plurality of light assembly means;

means for processing said decoded message data generated by said decoding means in each of said plurality of light assembly means;

means for providing data communication between each of said light assembly means and said processing means; and

said processing means comprises means for providing a graphic display of said airport comprising symbols representing said aircraft and other vehicles, each of said symbols having said identification message data displayed.

11. The vehicle identification system as recited in Claim 10 wherein:

said message data further includes position information.

12. The vehicle identification system as recited in Claim 10 wherein:

said plurality of light assembly means being arranged in two parallel rows along runways and taxiways of said airport.

13. The vehicle identification system as recited in Claim 10 wherein said light assembly means comprises:

light means coupled to said lines of said power providing means for lighting said airport;

vehicle sensing means for detecting aircraft or other vehicles on said airport;

said microprocessor means coupled to said decoding means, said light means, said vehicle sensing means and said data communication means further processes a detection signal from said vehicle sensing means; and

said data communication means being coupled to said microprocessor means and said lines of said power providing means.

14. The vehicle identification system as recited in Claim 10 wherein:

said symbols representing aircraft and other vehicles comprise icons having a shape indicating type of aircraft or vehicle.

15. The vehicle identification system as recited in Claim 10 wherein:

said processing means determines a location of said symbols on said graphic display of said airport in accordance with data received from said light assembly means.

16. A vehicle identification system for surveillance and identification of aircraft and other vehicles on an airport comprising:

a plurality of light circuits on said airport, each of said light circuits comprises a plurality of light assembly means;

means for providing power to each of said plurality of light circuits and to each of said light assembly means;

means in each of said light assembly means for sensing ground traffic on said airport;

means disposed on said aircraft and other vehicles for transmitting identification message data;

means disposed in each of said light assembly means for receiving and decoding said message data from said transmitting means;

means for processing ground traffic data from said sensing means and decoded message data from each of said light assembly means for presentation on a graphic display of said airport;

means for providing data communication between each of said light assembly means and said processing means; and

said processing means comprises means for providing such graphic display of said airport comprising symbols representing said ground traffic, each of said symbols having direction, velocity and said identification message data displayed.

17. The vehicle identification system as recited in Claim 16 wherein:
each of said light circuits being located along the edges of taxiways or runways on said airport.

18. The vehicle identification system as recited in Claim 16 wherein:
said sensing means comprises infrared detectors.

19. The vehicle identification system as recited in Claim 16 wherein said transmitting means comprises:
means for creating unique message data which includes aircraft and flight identification; and
infrared means coupled to said message creating means for transmitting a coded stream of said message data.

20. The vehicle identification system as recited in Claim 19 wherein:
said message data further comprises position information.

21. The vehicle identification system as recited in Claim 16 wherein:
said receiving and decoding means comprises an infrared sensor.

22. The vehicle identification system as recited in Claim 21 wherein:
said receiving and decoding means comprises microprocessor means coupled to said infrared sensor for decoding said message data.

23. The vehicle identification system as recited in Claim 16 wherein:
said plurality of light assembly means of said light circuits being arranged in two parallel rows along runways and taxiways of said airport.

24. The vehicle identification system as recited in Claim 16 wherein said light assembly means comprises:
light means coupled to said lines of said power providing means for lighting said airport;
said ground traffic sensing means for detecting aircraft or other vehicles on said airport;
microprocessor means coupled to said receiving and decoding means, said light means, said ground traffic sensing means and said data communication means for decoding said identification message data and processing a detection signal from said ground traffic sensing means; and
said data communication means being coupled to said microprocessor means and said lines of said power providing means.

25. The vehicle identification system as recited in Claim 24 wherein:
said light assembly means further comprises a photocell means coupled to said microprocessor means for detecting the light intensity of said light means.

26. The vehicle identification system as recited in Claim 24 wherein:
said light assembly means further comprises a strobe light coupled to said microprocessor means.

27. The vehicle identification system as recited in Claim 16 wherein:
said processing means comprises redundant computers for fault tolerance operation.

28. The vehicle identification system as recited in Claim 16 wherein:
said symbols representing said ground traffic comprise icons having a shape indicating type of aircraft or vehicle.

29. The vehicle identification system as recited in Claim 16 wherein:
said processing means determines a location of said symbols on said graphic display of said airport in accordance with said data receive from said light assembly means.

30. The vehicle identification system as recited in Claim 16 wherein:
said processing means determines a future path of said ground traffic based on a ground clearance command, said future path being shown on said graphic display.

31. The vehicle identification system as recited in Claim 16 wherein:
said processing means further comprises means for predicting an airport incursion.

32. The vehicle identification system as recited in Claim 16 wherein said power providing means comprises:

constant current power means for providing a separate line to each of said plurality of light circuits; and

network bridge means coupled to said constant current power means for providing a communication channel to said processing means for each line of said constant current power means.

33. A method of providing a vehicle identification system for identifying aircraft and other vehicles on surface pathways including runways and other areas of an airport comprising the steps of:

transmitting identification message data with means disposed on said aircraft and other vehicles;

receiving and decoding said message data from said transmitting means with means disposed in each of a plurality of light assembly means on said airport;

providing power to each of said plurality of light assembly means;

processing said decoded identification message data generated by said receiving and decoding means in each of said plurality of light assembly means;

providing data communication on lines of said power providing means between each of said light assembly means and said processing means; and

providing a graphic display of said airport with said processing means comprising symbols representing said aircraft and other vehicles, each of said symbols having said identification message data displayed.

34. The method as recited in Claim 33 wherein said step of transmitting identification message data comprises the steps of creating unique message data which includes aircraft and flight identification; and

transmitting a coded stream of said message data with infrared means coupled to said message creating means.

35. The method as recited in Claim 34 wherein said step of transmitting message data further includes transmitting position information.

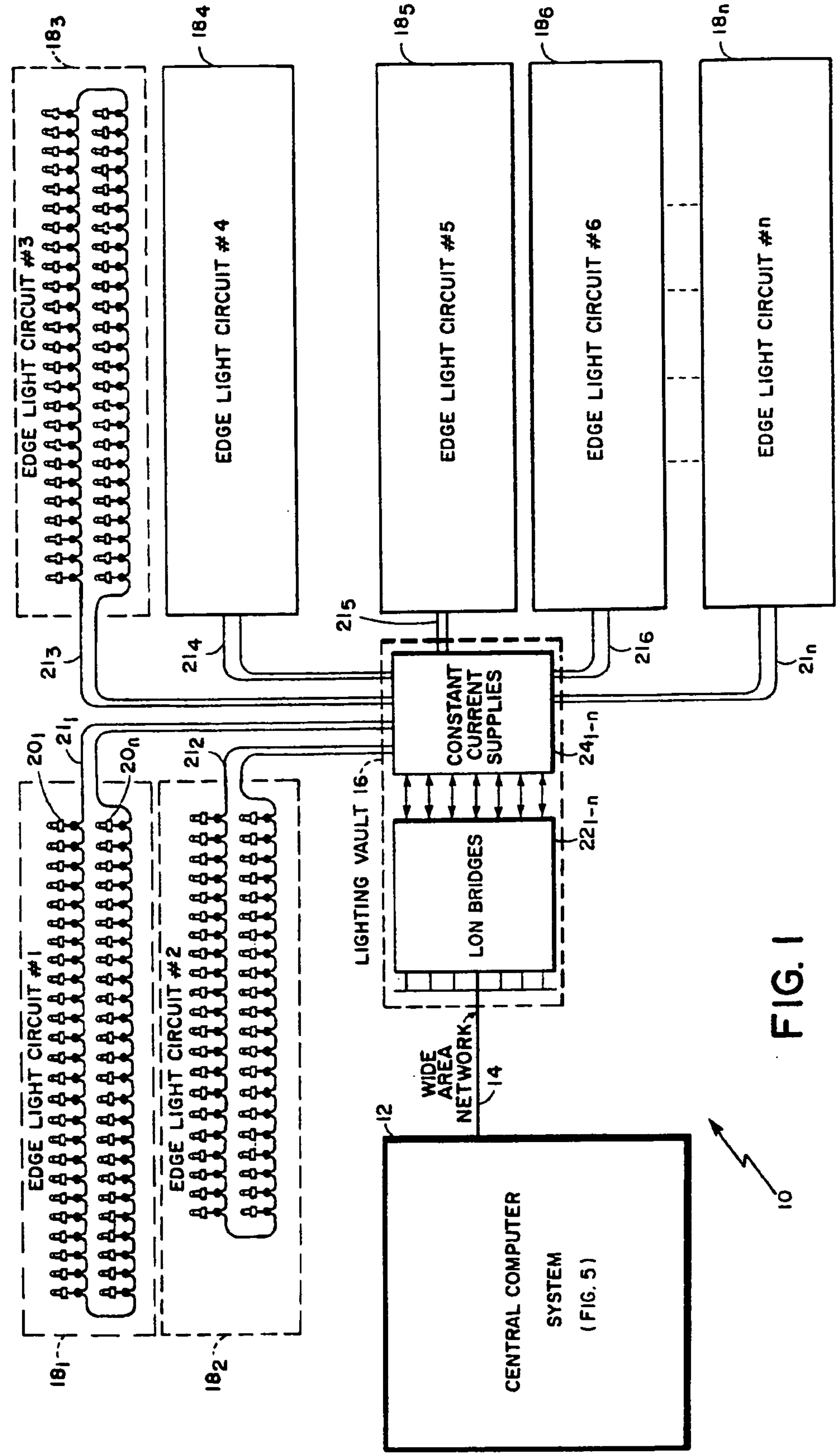
36. The method as recited in Claim 33 wherein said step of receiving and decoding said message data includes using an infrared sensor.

37. The method as recited in Claim 33 wherein said step of receiving and decoding said message data further comprises the step of coupling microprocessor means to said infrared sensor for decoding said message data.

38. The method as recited in Claim 33 wherein said step of receiving and decoding said message data with means disposed in said plurality of light assembly means further comprises the step of arranging said plurality of light assembly means in two parallel rows along runways and taxiways of said airport.

39. The method as recited in Claim 33 wherein said step of providing a graphic display comprising symbols representing aircraft and other vehicles further comprises the step of providing icons having a shape indicating type of aircraft or vehicle.

40. The method as recited in Claim 33 wherein said step of providing a graphic display comprises the step of determining a location of said symbols on said graphic display of said airport in accordance with data received from said light assembly means.



EDGE LIGHT CIRCUIT #1
EDGE LIGHT CIRCUIT #2
EDGE LIGHT CIRCUIT #3
EDGE LIGHT CIRCUIT #4
EDGE LIGHT CIRCUIT #5
EDGE LIGHT CIRCUIT #6
EDGE LIGHT CIRCUIT #n
18_1
18_2
18_3
18_4
18_5
18_6
18_n
20_1
20_n
21_1
21_2
21_3
21_4
21_5
21_6
21_n
CONSTANT CURRENT SUPPLIES
24_{1-n}
LON BRIDGES
22_{1-n}
LIGHTING VAULT 16
WIDE AREA NETWORK
14
12
CENTRAL COMPUTER SYSTEM (FIG. 5)
10

FIG. 1

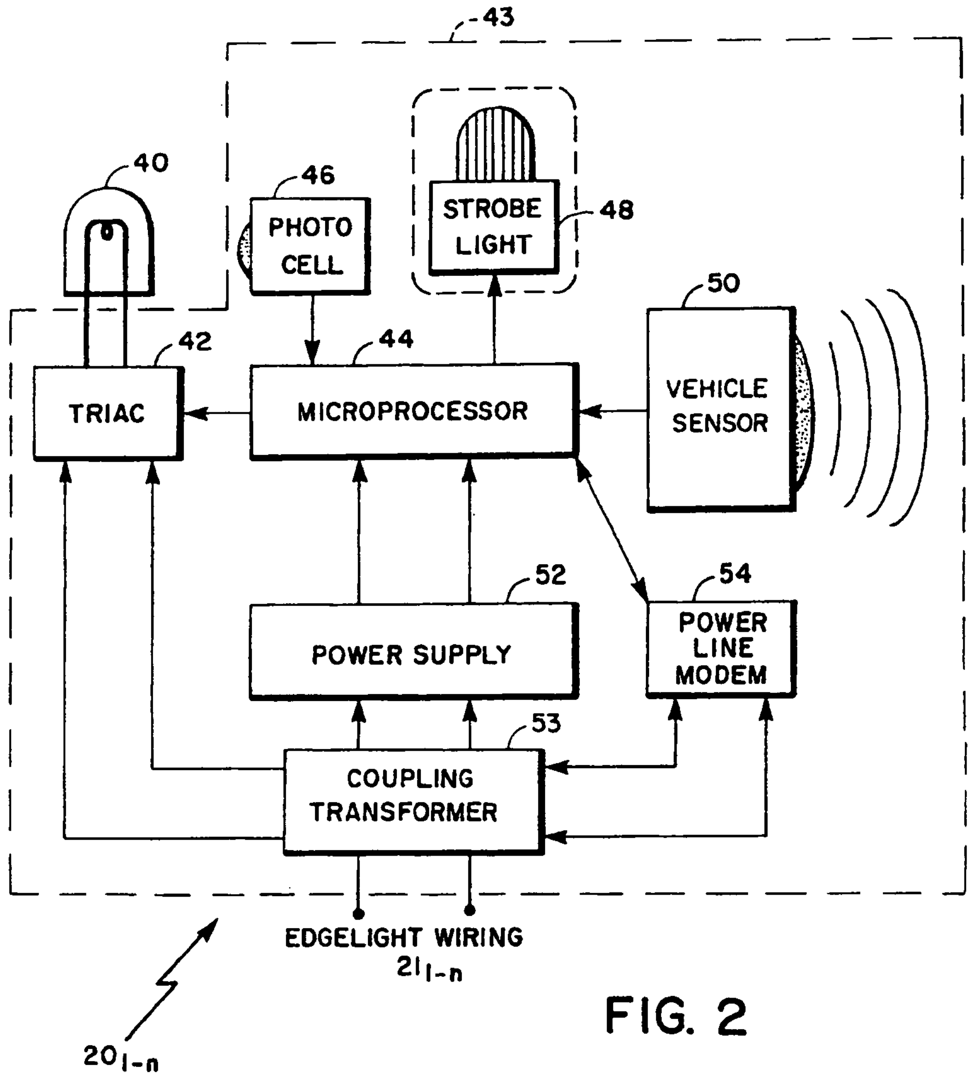

43
40
46
PHOTO CELL
STROBE LIGHT
48
50
42
44
TRIAC
MICROPROCESSOR
VEHICLE SENSOR
52
54
POWER SUPPLY
POWER LINE MODEM
53
COUPLING TRANSFORMER
EDGELIGHT WIRING
21_{1-n}
20_{1-n}

FIG. 2

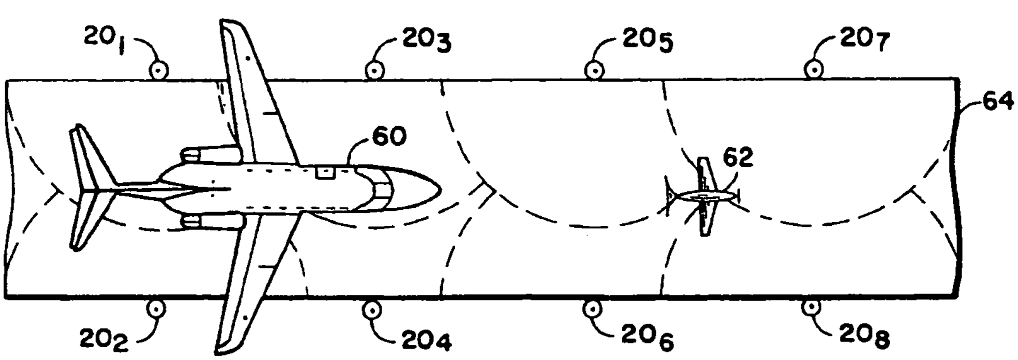

20_1
20_3
20_5
20_7
64
60
62
20_2
20_4
20_6
20_8

FIG. 4

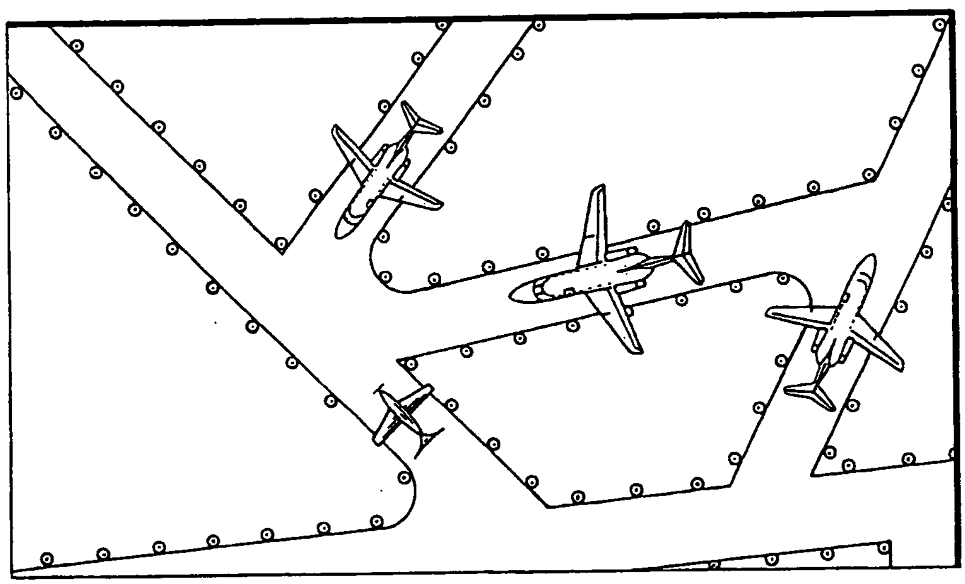


FIG. 8

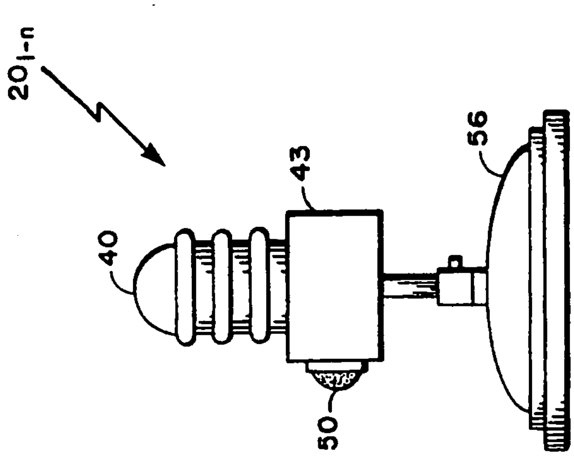


FIG. 3

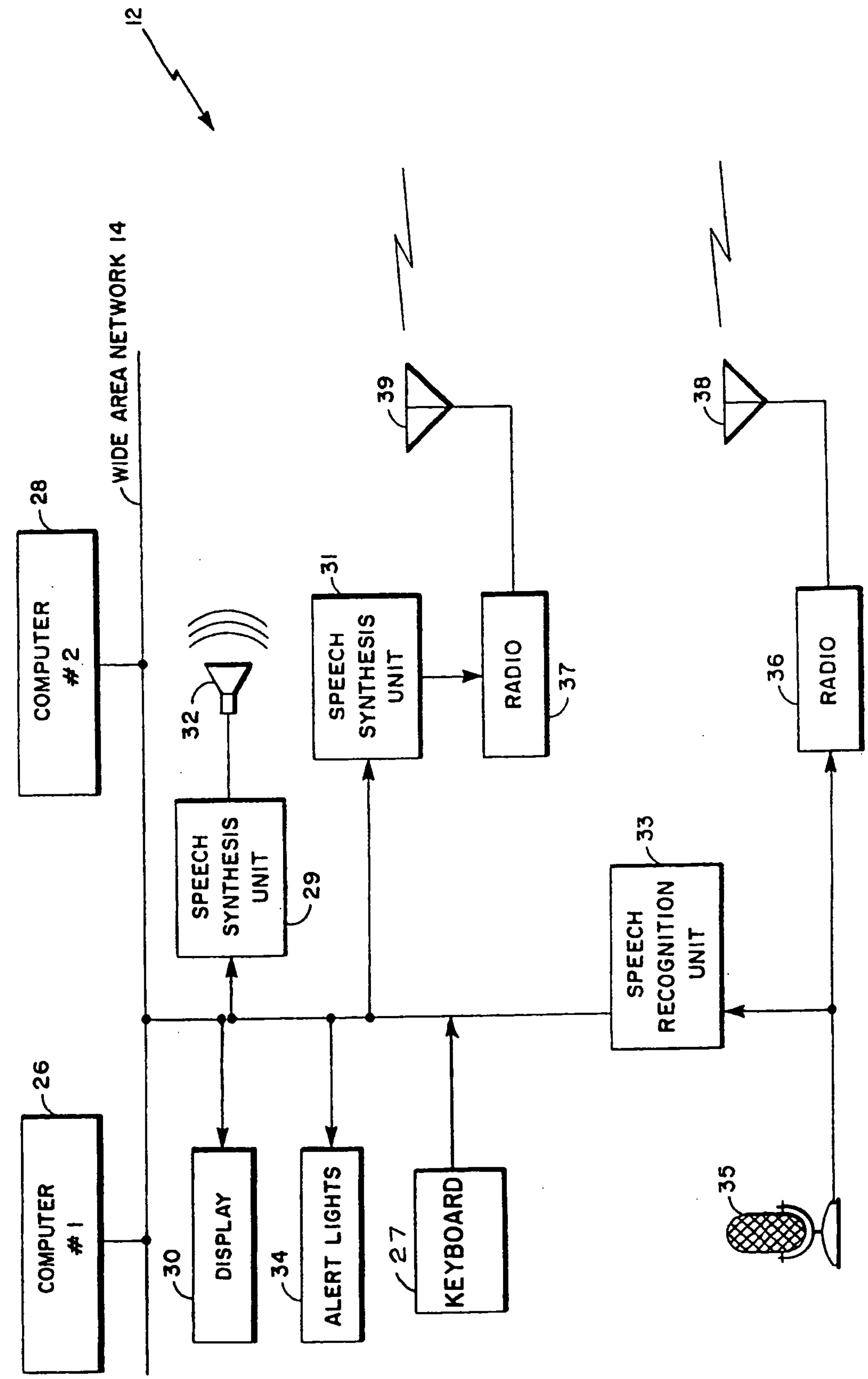

12
WIDE AREA NETWORK 14
COMPUTER #2
28
COMPUTER #1
26
SPEECH SYNTHESIS UNIT
29
32
SPEECH SYNTHESIS UNIT
31
RADIO
37
39
RADIO
36
38
SPEECH RECOGNITION UNIT
33
DISPLAY
30
ALERT LIGHTS
34
KEYBOARD
27
35

FIG. 5

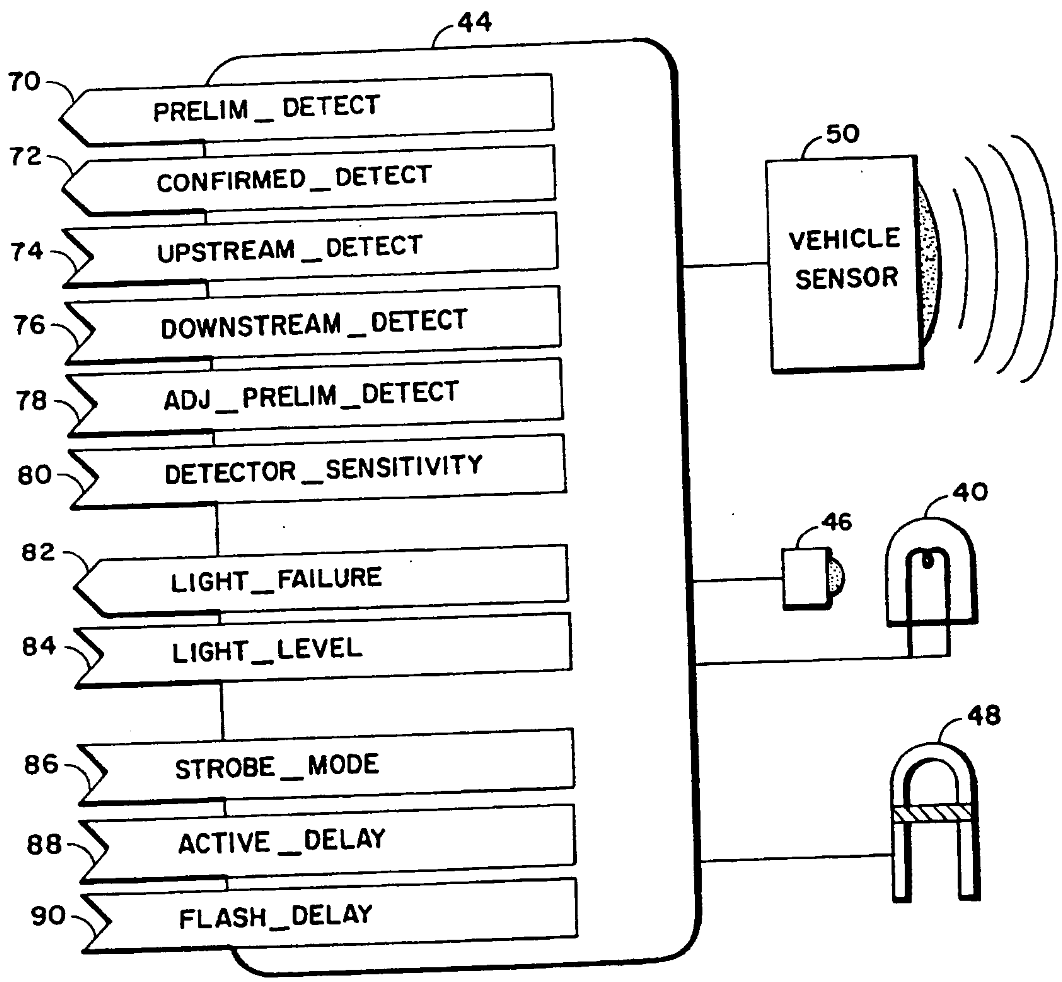

44
70
PRELIM _ DETECT
72
CONFIRMED _ DETECT
74
UPSTREAM _ DETECT
76
DOWNSTREAM _ DETECT
78
ADJ _ PRELIM _ DETECT
80
DETECTOR _ SENSITIVITY
82
LIGHT _ FAILURE
84
LIGHT _ LEVEL
86
STROBE _ MODE
88
ACTIVE _ DELAY
90
FLASH _ DELAY
50
VEHICLE SENSOR
46
40
48

FIG. 6

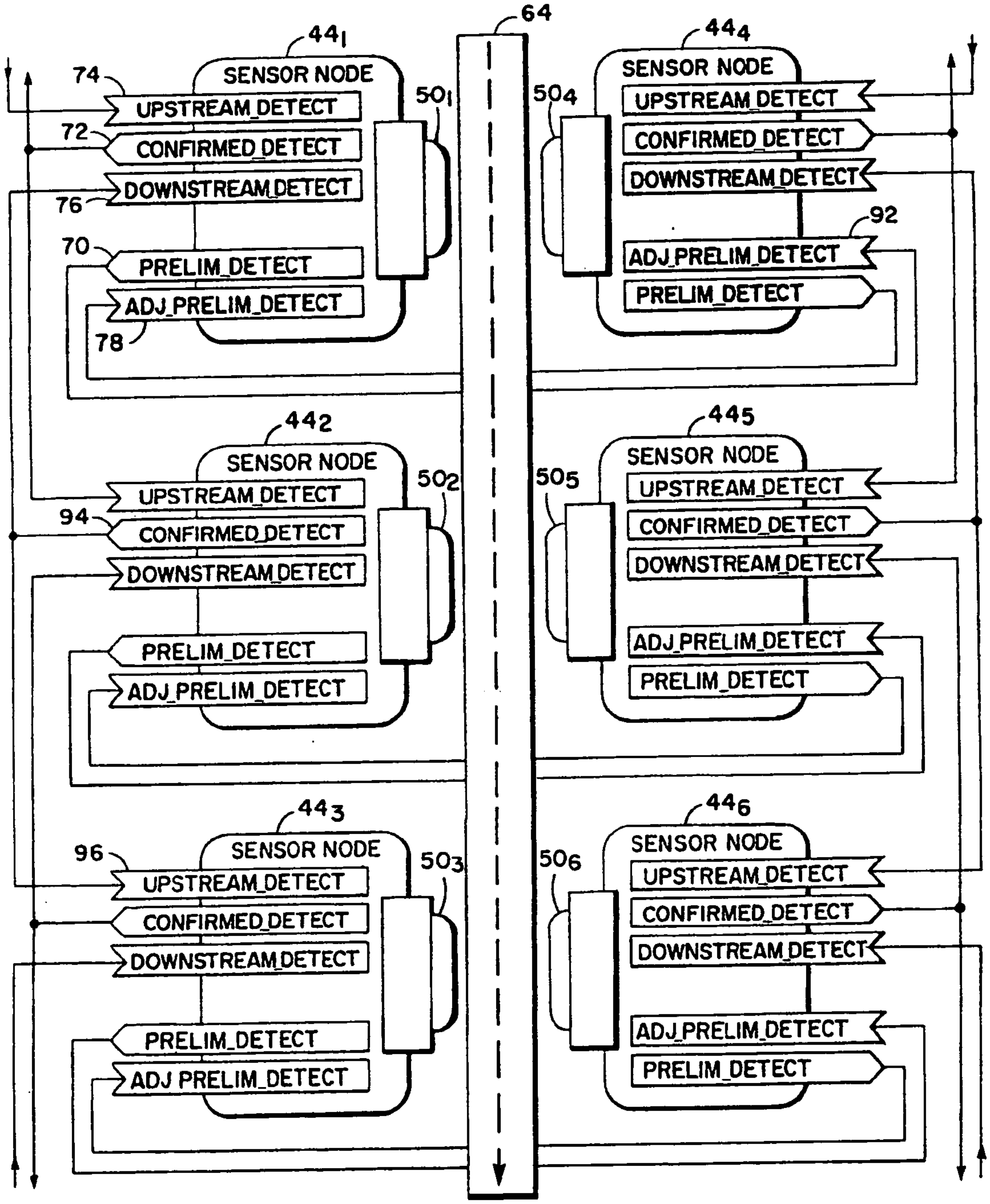

64
44_1
SENSOR NODE
74
UPSTREAM_DETECT
72
CONFIRMED_DETECT
DOWNSTREAM_DETECT
76
70
PRELIM_DETECT
ADJ_PRELIM_DETECT
78
50_1
50_4
44_4
SENSOR NODE
UPSTREAM_DETECT
CONFIRMED_DETECT
DOWNSTREAM_DETECT
92
ADJ_PRELIM_DETECT
PRELIM_DETECT
44_2
SENSOR NODE
UPSTREAM_DETECT
94
CONFIRMED_DETECT
DOWNSTREAM_DETECT
PRELIM_DETECT
ADJ_PRELIM_DETECT
50_2
50_5
44_5
SENSOR NODE
UPSTREAM_DETECT
CONFIRMED_DETECT
DOWNSTREAM_DETECT
ADJ_PRELIM_DETECT
PRELIM_DETECT
44_3
96
SENSOR NODE
UPSTREAM_DETECT
CONFIRMED_DETECT
DOWNSTREAM_DETECT
PRELIM_DETECT
ADJ PRELIM_DETECT
50_3
50_6
44_6
SENSOR NODE
UPSTREAM_DETECT
CONFIRMED_DETECT
DOWNSTREAM_DETECT
ADJ_PRELIM_DETECT
PRELIM_DETECT

FIG. 7

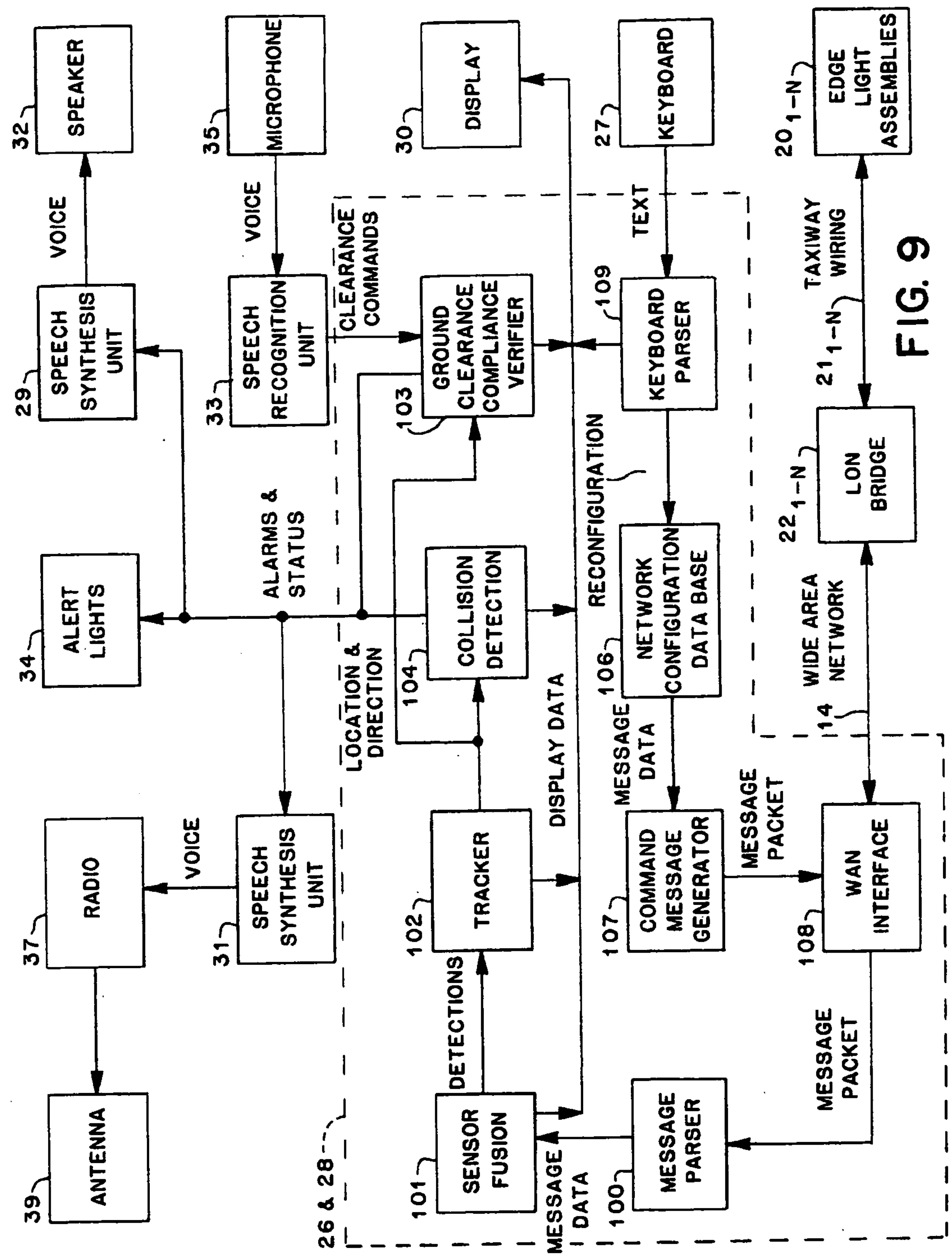

32
SPEAKER
VOICE
29
SPEECH SYNTHESIS UNIT
35
MICROPHONE
VOICE
33
SPEECH RECOGNITION UNIT
CLEARANCE COMMANDS
30
DISPLAY
27
KEYBOARD
TEXT
109
KEYBOARD PARSER
103
GROUND CLEARANCE COMPLIANCE VERIFIER
20 1-N
EDGE LIGHT ASSEMBLIES
TAXIWAY WIRING
21 1-N
22 1-N
LON BRIDGE
34
ALERT LIGHTS
ALARMS & STATUS
104
COLLISION DETECTION
RECONFIGURATION
106
NETWORK CONFIGURATION DATA BASE
WIDE AREA NETWORK
14
LOCATION & DIRECTION
DISPLAY DATA
MESSAGE DATA
MESSAGE PACKET
37
RADIO
VOICE
31
SPEECH SYNTHESIS UNIT
102
TRACKER
107
COMMAND MESSAGE GENERATOR
108
WAN INTERFACE
DETECTIONS
MESSAGE PACKET
39
ANTENNA
26 & 28
101
SENSOR FUSION
MESSAGE DATA
100
MESSAGE PARSER

FIG. 9

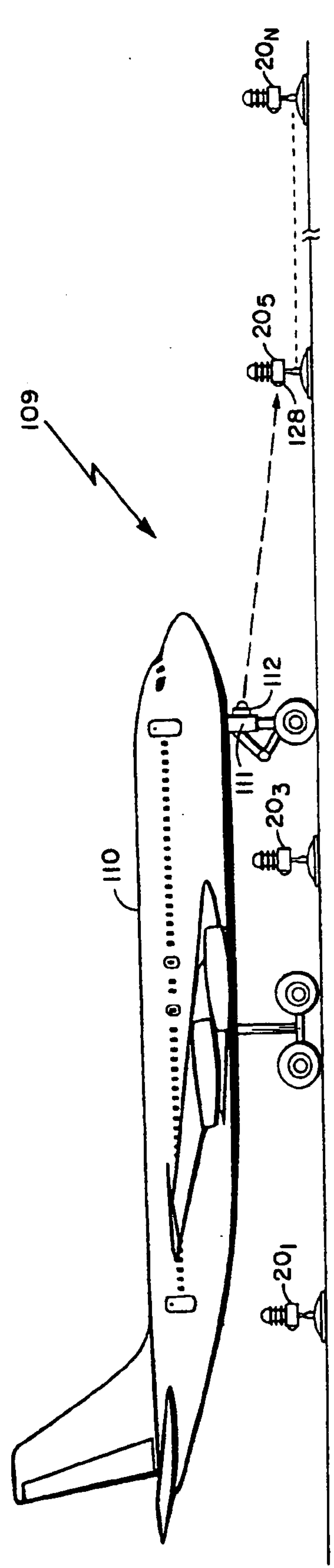

109
110
111
112
128
20_1
20_3
20_5
20_N

FIG. 10

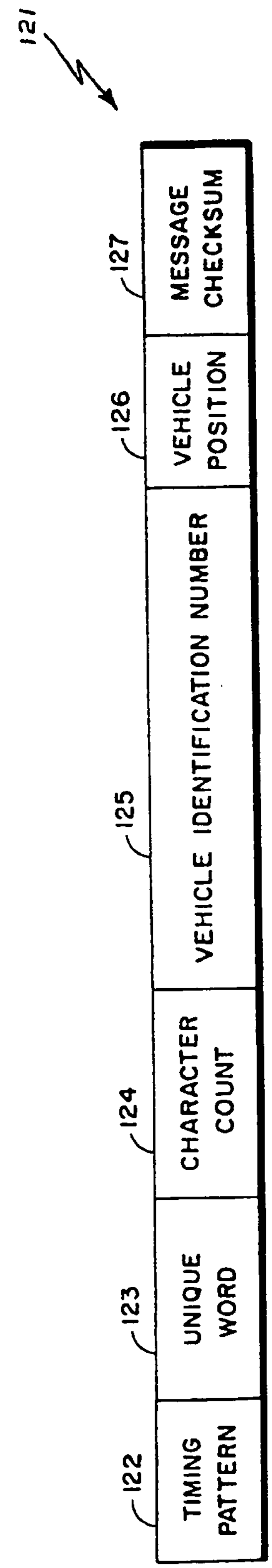

121
122
TIMING PATTERN
123
UNIQUE WORD
124
CHARACTER COUNT
125
VEHICLE IDENTIFICATION NUMBER
126
VEHICLE POSITION
127
MESSAGE CHECKSUM

FIG. 13

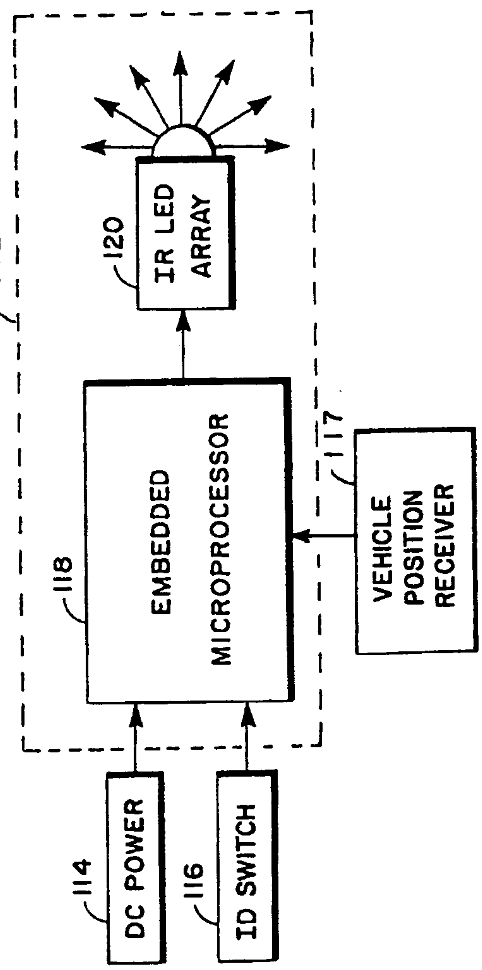

112
120
IR LED ARRAY
118
EMBEDDED MICROPROCESSOR
117
VEHICLE POSITION RECEIVER
114
DC POWER
116
ID SWITCH

FIG. 11

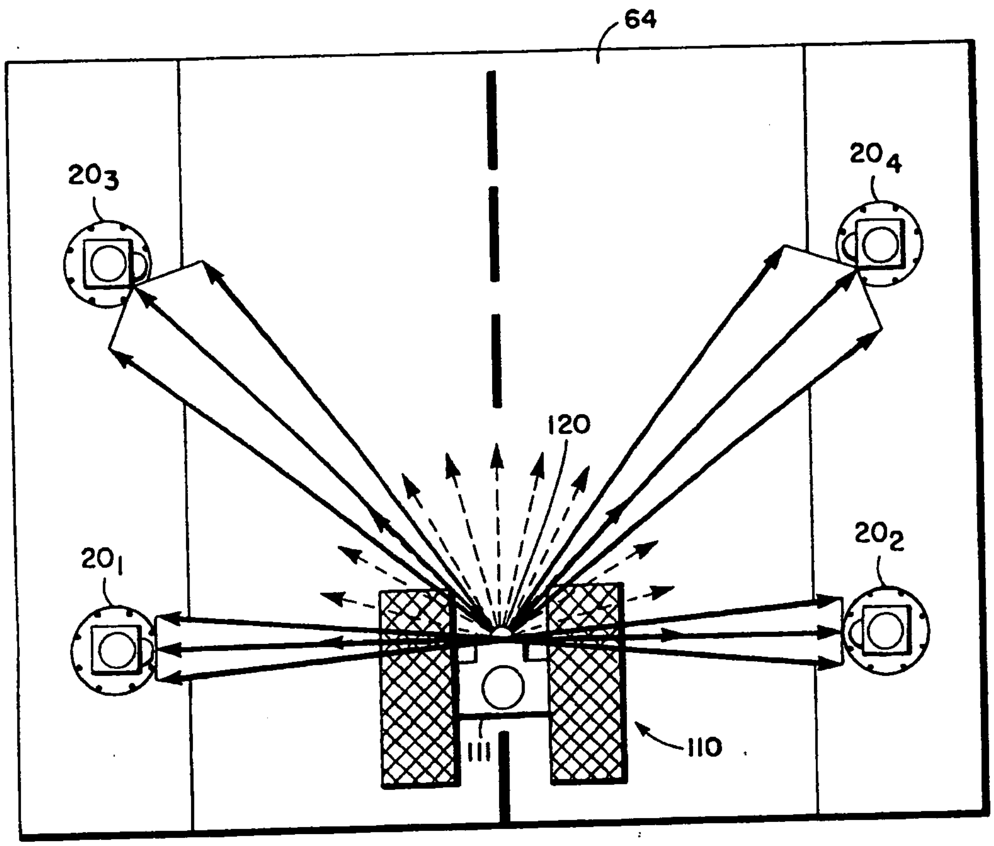


FIG. 12

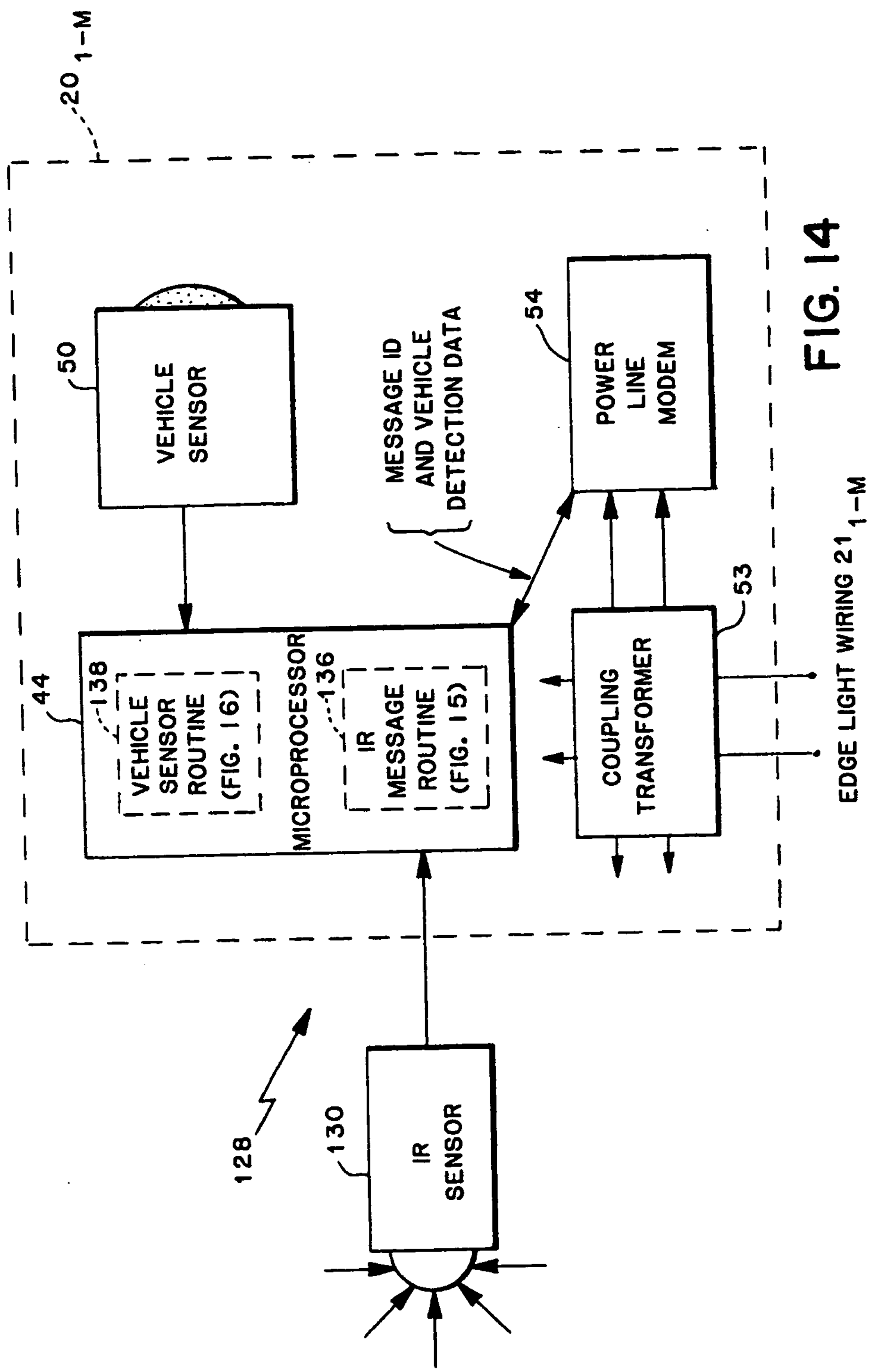

20 1-M
50
VEHICLE SENSOR
MESSAGE ID AND VEHICLE DETECTION DATA
54
POWER LINE MODEM
44
138
VEHICLE SENSOR ROUTINE (FIG. 16)
MICROPROCESSOR
136
IR MESSAGE ROUTINE (FIG. 15)
COUPLING TRANSFORMER
53
EDGE LIGHT WIRING 21 1-M
128
130
IR SENSOR

FIG. 14

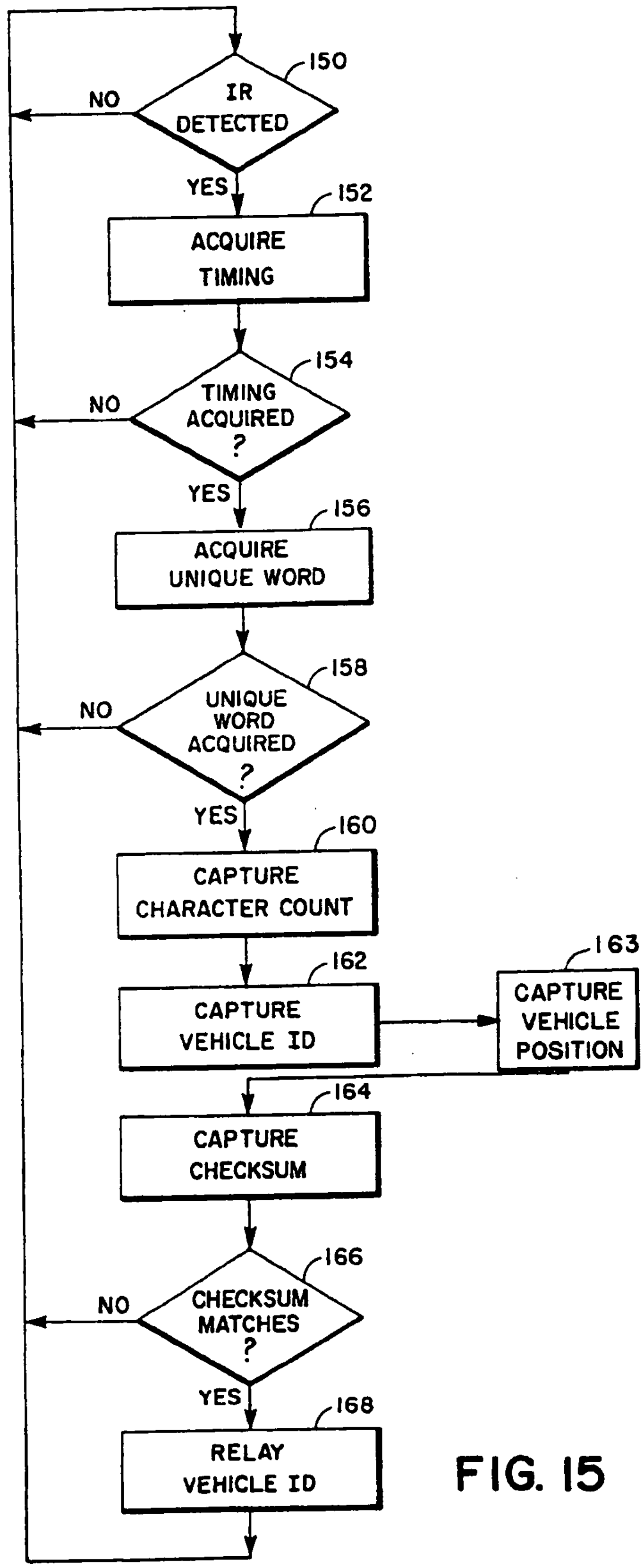

150
IR
DETECTED
NO
YES
152
ACQUIRE
TIMING
154
TIMING
ACQUIRED
?
NO
YES
156
ACQUIRE
UNIQUE WORD
158
UNIQUE
WORD
ACQUIRED
?
NO
YES
160
CAPTURE
CHARACTER COUNT
162
CAPTURE
VEHICLE ID
163
CAPTURE
VEHICLE
POSITION
164
CAPTURE
CHECKSUM
166
CHECKSUM
MATCHES
?
NO
YES
168
RELAY
VEHICLE ID

FIG. 15

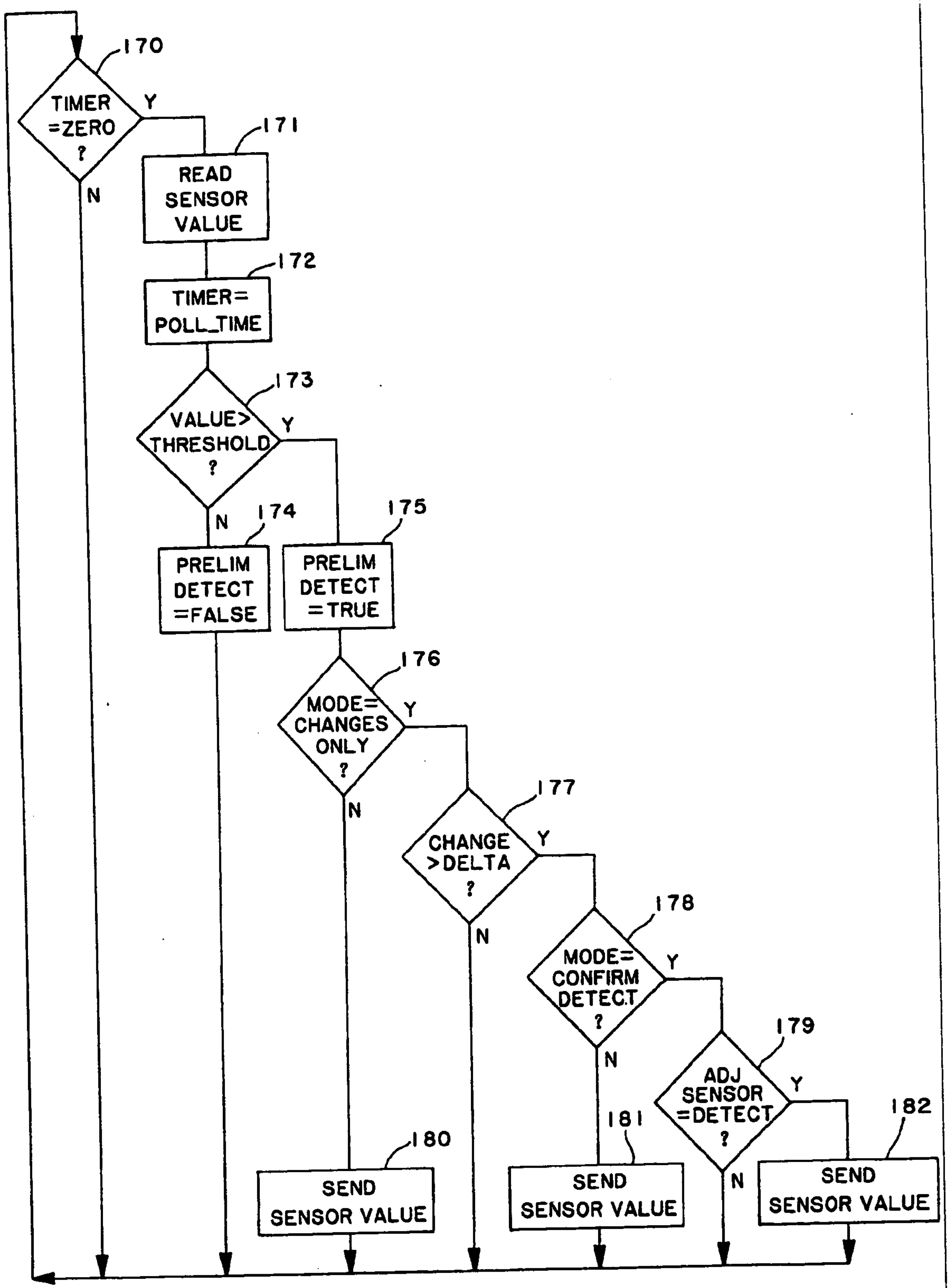

170
TIMER =ZERO ?
Y
N
171
READ SENSOR VALUE
172
TIMER= POLL_TIME
173
VALUE> THRESHOLD ?
Y
N
174
PRELIM DETECT =FALSE
175
PRELIM DETECT =TRUE
176
MODE= CHANGES ONLY ?
Y
N
177
CHANGE >DELTA ?
Y
N
178
MODE= CONFIRM DETECT ?
Y
N
179
ADJ SENSOR =DETECT ?
Y
N
180
SEND SENSOR VALUE
181
SEND SENSOR VALUE
182
SEND SENSOR VALUE

FIG. 16

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 94 30 1261

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.5)
Y	US-A-3 855 571 (MASSA) * the whole document *	1-40	G08G5/06
Y	WO-A-90 04242 (SWEDISH AIRPORT TECHNOLOGY HB) * the whole document *	1-40	
Y	FR-A-2 620 551 (RINALDI) * the whole document *	2-5,10, 16,18, 21,22, 33,36,37	
Y	EP-A-0 209 397 (GENERAL DE INVESTIGACION Y DESARROLLO S.A.) * claims 1,5-13,23,27 *	7-9, 13-15, 24,39,40	
D	& US-A-4 845 629 (MURGA ET AL.)		
Y	US-A-4 093 937 (HABINGER) * column 2, line 3 - line 33 *	26	TECHNICAL FIELDS SEARCHED (Int.Cl.5)
Y	US-A-3 706 969 (PAREDES) * column 3, line 18 - column 4, line 59 * * column 22, line 57 - column 23, line 28 *	30,31	G08G

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	20 June 1994	Reekmans, M

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
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P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 :
G08G 5/06, B64F 1/00

A1

(11) International Publication Number: WO 96/12265

(43) International Publication Date: 25 April 1996 (25.04.96)

(21) International Application Number: PCT/SE94/00968

(22) International Filing Date: 14 October 1994 (14.10.94)

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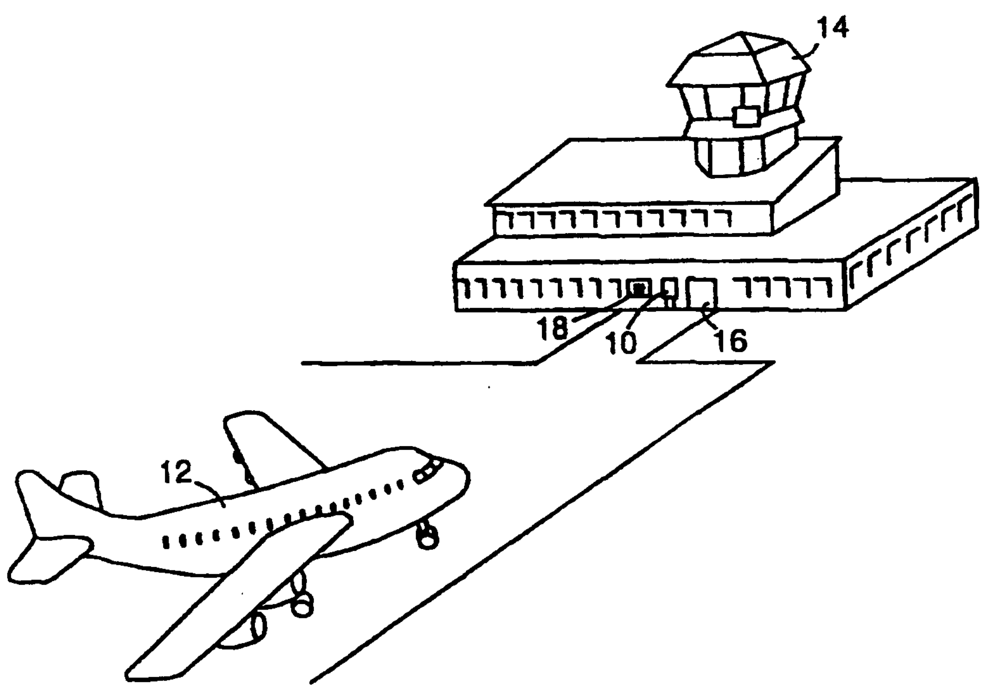
(81) Designated States: AM, AT, AU, BB, BG, BR, BY, CA, CH, CN, CZ, DE, DK, EE, ES, FI, GB, GE, HU, JP, KE, KG, KP, KR, KZ, LK, LT, LU, LV, MD, MG, MN, MW, NL, NO, NZ, PL, PT, RO, RU, SD, SE, SI, SK, TJ, TT, UA, US, UZ, VN, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG), ARIPO patent (KE, MW, SD, SZ).

Published
With international search report.

(54) Title: AIRCRAFT IDENTIFICATION AND DOCKING GUIDANCE SYSTEMS



(57) Abstract

A system for detecting, identifying and docking aircraft using laser pulses to obtain a profile of an object in the distance. The system initially scans the area in front of the gate until it locates and identifies an object. Once the identity of the object is known, the system tracks the object. By using the information from the profile, the system can in real time display the type of airplane, the distance from the stopping point and the lateral position of the airplane.

AIRCRAFT IDENTIFICATION AND DOCKING GUIDANCE SYSTEMS

BACKGROUND OF THE INVENTION

Field Of The Invention

This invention relates to systems for locating, identifying and tracking objects. More particularly, it relates to aircraft location, identification and docking guidance systems and to ground traffic control methods for locating and identifying objects on an airfield and for safely and efficiently docking aircraft at such airport.

Description Of Related Art

In recent years there has been a significantly increased amount of passenger, cargo and other aircraft traffic including take offs, landings and other aircraft ground traffic. Also there has been a marked increase in the number of ground support vehicles which are required to off load cargo, provide catering services and on going maintenance and support of all aircraft. With this substantial increase in ground traffic has come a need for greater control and safety in the docking and identification of aircraft on an airfield.

Examplary of prior art systems which have been poposed for detecting the presence of aircraft and other traffic on an airfield are those systems disclosed in U.S. Patent 4,995,102; European Patent No. 188 757; and PCT Published Applications W0 93/13104 and W0 93/15416.

However, none of those systems have been found to be satisfactory for detection of the presence of aircraft on an airfield, particularly, under adverse climatic conditions causing diminished visibility such as encountered under fog, snow or sleet conditions. Furthermore, none of the systems disclosed in the prior references are capable of identifying and verifying the specific configuration of an approaching aircraft. Still further, none of the prior systems provide adequate techniques for tracking and docking an aircraft at a designated stopping point such as an airport loading gate. Also, none of the prior systems have provided techniques which enable adequate calibration of the instrumentation therein.

Thus, it has been a continuing problem to provide systems which are sufficiently safe and reliable over a wide range of atmospheric conditions to enable detection of objects such as aircraft and other ground traffic on an airfield.

In addition, there has been a long standing need for systems which are not only capable of detecting objects such as aircraft, but which also provide for the effective

identification of the detected object and verification of the identity of such object, for example, a detected aircraft with the necessary degree of cetainty regardless of prevailing weather conditions and magnitude of ground traffic.

There has also been a long standing, unfulfilled need for systems which are capable of accurately and efficiently tracking and guiding objects such as incoming aircraft to a suitable stopping point such as an airport loading gate. In addition, the provision of accurate and effective calibration techniques for such systems has been a continuing problem requiring resolution.

SUMMARY OF THE INVENTION

In order to overcome the foregoing problems, systems and methods are required which are capable of achieving accurate, safe, efficient and cost effective location of objects such as aircraft on an airfield and for proper identification and verification of the identity of such objects. In addition, systems and methods are required for tracking and docking guidance of objects such as aircraft, particularly, in a real time operating mode. Furthermore, systems and methods are required for calibration of such operating systems.

Accordingly, it is a primary object of the present invention to provide such systems and methods. In this regard, it is a specific object of the present invention to provide docking guidance systems whieh are capable of determining the precise position as well as verifying the identity of aircraft on an airfield. Another object of the invention is to provide information to an individual or individuals controlling the docking or parking of aircraft on an airfield via a display unit utilizing communications between the system and a personal computer and other methods for monitoring the overall method operation.

A further object is to provide the safety of digitally precise docking control and, also, to provide for implementation of such control in an extremely cost effect manner.

A still further object is to provide for the display of aircraft docking information for use by a pilot, co-pilot or other personnel docking an aircraft including information concerning the closing rate distance from an appropriate stopping point for the aircraft. Another significant object is to provide for the automatic comparison and determination that the aircraft positioning and incoming direction does not deviate from the appropriate path necessary for the particular type of aircraft being docked and. particularly, to provide visual feedback as to the closing distance in a countdown format from a display, positioned forward of the aircraft which contains the distance for docking. position to left or right of appropriate center line for docking and a check of the aircraft type.

Yet another object is to provide systems which not only provide azimuth guidance to either the pilot or the co-pilot, but also provide for scanning of the apron to enable appropriate and safe docking of an aircraft. Another object is to provide systems which are particularly sensitive so that accurate parking positions are achieved within extremely minimal tolerances.

A further object is to provide systems which are extremely flexible and allow for the implementation of new operational parameters such as adding new aircraft types, alternate or secondary parking stop positions and other related information in regard to identifying, guiding and docking aircraft on an airfield.

These and other objects of the invention are accomplished by providing systems and methods for detecting the presence of an object on an airfield employing light pulses such as laser pulses projected, for example, off of mirrors in the direction of an incoming object positioned within a capture zone on the airfield and collecting light pulses reflected off the object which indicates the presence of the object. Likewise, this technique enables the determination of the aircraft's position within the capture zone as well as the detection thereof.

The present invention also provides systems and methods for verifying the identity of the detected object which, for example, enables a determination that the correct type of aircraft is approaching the docking facility and is to be docked therein. Such verification systems and methods involve the projection of light pulses such as laser pulses in angular coordinates onto an object and collecting reflected pulses off of the object in a detection device which enables a comparison of the reflected pulses to be made with a profile corresponding to the shape of a known object in order to determine whether the detected shape corresponds to the known shape.

Furthermore, the present invention provides systems and methods for tracking incoming objects wherein light pulses such as laser pulses are projected onto an incoming object and the light reflected from the object is collected and employed in order to assertain the position of the object relative to an imaginary axial line projecting from a predetermined docking point and to detect the distance between the object and the predetermined point for purposes of determining the location of the object.

Thus, the present invention provides for the location or capture of an approaching aircraft and for the identification or recognition of its shape within a designated capture zone or control area which is essential in initiating an aircraft docking procedure. Thereafter, in accordance with the present invention, a display is provided which enables

docking of the identified aircraft in an appropriate docking area for off loading of passengers, cargo and the like.

The present invention accomplishes these features while eliminating the heretofore standard need for sensors which must be embedded in the apron of the docking areas. This results in a significant reduction not only in installation time and associated costs but, also, reduces maintenance costs thereafter. Furthermore, this invention permits retrofitting of the present systems into existing systems without requiring apron construction and the accompanying interruption in use of the airport docking areas which has been required with prior devices previously used for docking guidance systems.

In preferred embodiments of the systems of the present invention, a pilot bringing an aircraft into a gate at an airport is provided with a real time display mounted, for example, above the gate which indicates the aircraft's position relative to the point where the pilot must start to brake the plane. Also displayed is the aircraft's lateral position compared to a predetermined line for a plane of its type to follow in order to most expeditiously arrive at the gate.

The software employed in the systems of the present invention preferably comprises four modules which perform the main computational tasks of the system and control the hardware. These modules include one for capture, one for identification, one for tracking and one for calibration of the system.

In a preferred embodiment of this invention, the capture module is employed to direct the devices for projecting light pulses to scan the area in front of a docking gate. Thus, when mirrors are employed to reflect and project pulses such as laser pulses, the capture module continues to direct the laser to scan this area until it detects an object entering the area. Once it detects an object, the capture module computes the distance and the angular position of the object and passes control onto the tracking module.

Once activated, the tracking module follows the incoming aircraft to the gate while providing information about its lateral location and distance relative to the desired stopping point. Using this information, the pilot can correct the course of the plane and brake at the precise point that will result in stopping the aircraft in a desired docking position in alignment with the gate. During the tracking, an identification module first scans the detected object to determine if its profile matches the reference profile of the type of aircraft expected. If the profiles do not match, the system informs the airport tower and a signal is transmitted for stopping the docking function.

Finally, the calibration module calibrates the distance and angular measurements to

ensure that the readings of the detection devices such as a Laser Range Finder accurately correspond to the distance and angle of the aircraft. This module runs periodically during the capture and tracking modules to determine the continued accuracy of the system.

BRIEF DESCRIPTION OF THE DRAWINGS

The features and advantages of the invention will become apparent from the following detailed description taken in connection with the accompanying drawings wherein:

Fig 1	is a view illustrating the system as in use at an airport;
Fig 2	is a diagrammatic view illustrating the general componentry of a preferred system in accordance with the present invention;.
Fig 3	is a top plan view illustrating the detection area in front of a docking gate which is established for purposes of detection and identification of approaching aircraft;
Fig 4	is a flow chart illustrating the main routine and the docking mode of the system;
Fig 5	is a flow chart illustrating the calibration mode of the system;
Fig 6	is a view illustrating the components of the calibration mode;
Fig 7	is a flow chart illustrating the capture mode of the system;
Fig 8	is a flow chart illustrating the tracking phase of the system;
Fig 9	is a flow chart illustrating the height measuring phase of the system; and
Fig 10	is a flow chart illustrating the identification phase of the system.
Table I	is a preferred embodiment of a Horizontal Reference Profile Table which is employed to establish the identity of an aircraft in the systems of the present invention;
Table II	is a preferred embodiment of a Comparison Table which is employed in the systems of the present invention for purposes of effectively and efficiently docking an aircraft;

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Reference is now made to Figures 1-10 and Tables I-II, in which like numerals designate like elements throughout the several views. Throughout the following detailed description, numbered stages depicted in the illustrated flow diagrams are generally indi-

cated by element numbers in parenthesis following such references.

Referring to Fig. 1, the systems of the present invention generally designated 10 in the drawings provide for the computerized location of an object, verification of the identity of the object and tracking of the object, the object preferably being an aircraft 12. In operation, once the control tower 14 lands an aircraft 12, it informs the system that a plane is approaching the gate 16 and the type of aircraft (i.e., 747, L-1011, etc.) expected. The system 10 then scans the area in front of the gate 16 until it locates an object that it identifies as an airplane 12. The system 10 then compares the profile of the aircraft 12 with a reference profile for the expected type of aircraft. If the located aircraft does not match the expected profile, the system informs or signals the tower 14 and shuts down.

If the object is the expected aircraft 12, the system 10 tracks it into the gate 16 by displaying in real time to the pilot the distance remaining to the proper stopping point 29 and the lateral position 31 of the plane 12. The lateral position 31 of the plane 12 is provided on a display 18 allowing the pilot to correct the position of the plane to approach the gate 16 from the correct angle. Once the airplane 12 is at its stopping point 53, this fact is shown on the display 18 and the pilot stops the plane. Employing the system 10 of the present invention, it should be noted that once the plane 12 comes to rest, it is accurately aligned with the gate 16 requiring no adjustment of the gate 16 by the ground staff.

Referring to Fig. 2, the system 10 consists of a Laser Range Finder (LRF) 20, two mirrors 21, 22, a display unit 18, two step motors 24, 25, and a microprocessor 26. Suitable LRF products for use herein are sold by Laser Atlanta Corporation and are capable of emitting laser pulses and receiving the reflections of those pulses reflected off of distant objects and computing the distance to those objects.

The system 10 is arranged such that there is a connection 28 between the serial port of the LRF 20 and the microprocessor 26. Through this connection, the LRF 20 sends measurement data approximately every 1/400th of a second to the microprocessor 26. The hardware components generally designated 23 of the system 10 are controlled by the programmed microprocessor 26. In addition, the microprosessor 26 feeds data to the display 18. As the interface to the pilot, the display unit 18 is placed above the gate 16 to show the pilot how far the plane is from its stopping point 29, the type of aircraft 30 the system believes is approaching and the lateral location of the plane 31. Using this display, the pilot can adjust the approach of the plane 12 to the gate 16 to ensure the plane is on the correct angle to reach the gate. If the display 18 is showing the wrong aircraft type 30,

the pilot can abort the approach before any damage is done. This double check ensures the safety of the passengers, plane and airport facilities because if the system tries to maneuver a larger 747 as if it was a 737, it likely will cause extensive damage.

In addition to the display 18, the microprocessor 26 processes the data from the LRF 20 and controls the direction of the laser 20 through its connection 32 to the step motors 24, 25. The step motors 24, 25 are connected to the mirrors 21, 22 and move them in response to instructions from the microprocessor 26. Thus, by controlling the step motors 24, 25, the microprocessor 26 can change the angle of the mirrors 21, 22 and aim the laser pulses from the LRF 20.

The mirrors 21, 22 aim the laser by reflecting the laser pulses outward over the tarmac of the airport. In the preferred embodiment, the LRF 20 does not move. The scanning by the laser is done with mirrors. One mirror 22 controls the horizontal angle of the laser while the other mirror 21 controls the vertical angle. By activating the step motors 24, 25, the microprocessor 26 controls the angle of the mirrors and thus the direction of the laser pulse.

The system 10 controls the horizontal mirror 22 to achieve a continuous horizontal scanning within a ±10 degree angle in approximately 0.1 degree angular steps which are equivalent to 16 microsteps per step with the Escap EDM-453 step motor. One angular step is taken for each reply from the reading unit, i.e., approximately every 2.5 ms. The vertical mirror 21 can be controlled to achieve a vertical scan between +20 and -30 degrees in approximately 0.1 degree angular steps with one step every 2.5 ms. The vertical mirror 21 is used to scan vertically when the nose height is being determined and when the aircraft 12 is being identified. During the tracking mode, the vertical mirror 21 is continuously adjusted to keep the horizontal scan tracking the nose tip of the aircraft 12.

Referring to Fig. 3, the system 10 divides the field in front of it by distance into three parts. The farthest section, from about 50 meters out, is the capture zone 50. In this zone 50, the system 10 detects the aircraft's nose and makes a rough estimate of lateral and longitudinal position of the aircraft 12. Inside the capture zone 50 is the identification area 51. In this area, the system 10 checks the profile of the aircraft 12 against a stored profile. The system 10 shows the lateral position of the aircraft 12 in this region, related to a predetermined line, on the display 18. Finally, nearest to the LRF 20 is the display or tracking area 52. In the display area 52, the system 10 displays the lateral and longitudinal position of the aircraft 12 relative to the correct stopping position with its highest degree of accuracy. At the end of the display area 52 is the stopping point 53. At the stopping point

53, the aircraft will be in the correct position at the gate 16.

In addition to the hardware and software, the system 10 maintains a database containing reference profiles for any type of aircraft it might encounter. Within this database, the system stores the profile for each aircraft type as a horizontal and vertical profile reflecting the expected echo pattern for that type of aircraft.

Referring to Table I, the system maintains the horizontal profile in the form of a Table I whose rows 40 are indexed by angular step and whose columns 41 are indexed by distance from the stopping position for that type of aircraft. In addition to the indexed rows, the table contains a row 42 providing the vertical angle to the nose of the plane at each distance from the LRF, a row 44 providing the form factor, k, for the profile and a row 45 providing the number of profile values for each profile distance. The body 43 of the Table I contains expected distances for that type of aircraft at various scanning angles and distances from the stopping point 53.

Theoretically, the 50 angular steps and the 50 distances to the stopping point 53 would require a Table I containing 50 x 50, or 2500, entries. However, the Table I will actually contain far fewer entries because the profile will not expect a return from all angles at all distances. It is expected that a typical table will actually contain between 500 and 1000 values. Well known programming techniques provide methods of maintaining a partially full table without using the memory required by a full table.

In addition to the horizontal profile, the system 10 maintains a vertical profile of each type of aircraft. This profile is stored in the same manner as the horizontal profile except its rows are indexed by angular steps in the vertical direction and its column index contains fewer distances from the stopping position than the horizontal profile. The vertical profile requires fewer columns because it is used only for identifying the aircraft 12 and for determining its nose height, which take place at a defined range of distances from the LRF 20 in the identification area 51. Consequently, the vertical profile stores only the expected echoes in that range without wasting data storage space on unneeded values.

The system 10 uses the previously described hardware and database to locate, identify and track aircraft using the following procedures:

Referring to Fig. 4, the software running on the microprocessor performs a main routine containing subroutines for the calibration mode 60, capture mode 62 and docking mode 64. The microprocessor first performs the calibration mode 60, then the capture mode 62 and then the docking mode 64. Once the aircraft 12 is docked, the program finishes. These modes are described in greater detail as follows:

Calibration Mode

To ensure system accuracy, the microprocessor 26 is programmed to calibrate itself in accordance with the procedure illustrated in Fig. 5 before capturing an aircraft 12 and at various intervals during tracking. Calibrating the system 10 ensures that the relationship between the step motors 24, 25 and the aiming direction is known. The length measuring ability of the LRF 20 is also checked.

Referring to Fig. 6, for calibration, the system 10 uses a square plate 66 with a known position. The plate 66 is mounted 6 meters from the LRF 20 and at the same height as the LRF 20.

To calibrate, the system sets (a,ß) to (0,0) causing the laser to be directed straight forward. The vertical mirror 22 is then tilted such that the laser beam is directed backwards to a rear or extra mirror 68 which redirects the beam to the calibration plate 66. (100) The microprocessor 26 then uses the step motors 24, 25 to move the mirrors 21, 22 until it finds the center of the calibration plate 66. Once it finds the center of the calibration plate 66, the microprocessor 26 stores the angles (α_{cp},β_{cp}) at that point and compares them to stored expected angles. (102) The system 10 also compares the reported distance to the plate 66 center with a stored expected value. (102) If the reported values do not match the stored values, the microprocessor 26 changes the calibration constants, which determine the expected values, until they do. (104, 106) However, if any of these values deviate too much from the values stored at installation, an alarm is given. (108)

Capture Mode

Initially, the airport tower 14 notifies the system 10 to expect an incoming airplane 12 and the type of airplane to expect. This signal puts the software into a capture mode 62 as outlined in Fig. 8. In capture mode 62, the microprocessor 26 uses the step motors 24, 25 to direct the laser to scan the capture zone 50 horizontally for the plane 12. This horizontal scan is done at a vertical angle corresponding to the height of the nose of the expected type of aircraft at the midpoint of the capture zone 50.

To determine the correct height to scan, the microprocessor 26 computes the vertical angle for the laser pulse as:

$$\beta_f = \arctan [(H-h)/l_f]$$

where H = the height of the LRF 20 above the ground, h = the nose height of the expected aircraft, and l_f = the distance from the LRF 20 to the middle of the capture zone 50. This equation results in a vertical angle for the mirror 21 that will enable the search to be at the correct height at the middle of the capture zone 50 for the expected airplane 12.

Alternatively, the system 10 can store in the database values for β_f for different types of aircraft at a certain distance. However, storing β_f limits the flexibility of the system 10 because it can capture an aircraft 12 only at a single distance from the LRF 20.

In the capture zone 50 and using this vertical angle, the microprocessor 26 directs the laser to scan horizontally in pulses approximately 0.1 degree apart. The microprocessor 26 scans horizontally by varying α, the horizontal angle from a center line starting from the LRF 20, between $\pm\alpha_{max}$, a value defined at installation. Typically, α_{max} is set to 50 which, using 0.1 degree pulses, is equivalent to 5 degrees and results in a 10 degree scan.

The release of the laser pulses results in echoes or reflections from objects in the capture zone 50. The detection device of the LRF 20 captures the reflected pulses, computes the distance to the object from the time between pulse transmission and receipt of the echo, and sends the calculated distance value for each echo to the microprocessor 26. The micro processor 26 stores, in separate registers in a data storage device, the total number of echoes or hits in each 1 degree sector of the capture zone 50. (70) Because the pulses are generated in 0.1 degree intervals, up to ten echoes can occur in each sector. The microprocessor 26 stores these hits in variables entitled s_α where α varies from 1 to 10 to reflect each one degree slice of the ten degree capture zone 50.

In addition to storing the number of hits per sector, the microprocessor 26 stores, again in a data storage device, the distance from the LRF 20 to the object for each hit or echo. Storing the distance to each reflection requires a storage medium large enough to store up to ten hits in each 1 degree of the capture zone 50 or up to 100 possible values. Because, in many cases, most of the entries will be empty, well known programming techniques can reduce these storage requirements below having 100 registers always allocated for these values.

Once this data is available for a scan, the microprocessor 26 computes the total number of echoes, S_T, in the scan by summing the s_α's. The microprocessor 26 then computes S_M, the largest sum of echoes in three adjacent sectors. (72) In other words, S_M is the largestsum of $(S_{\alpha-1}, S_\alpha, S_{\alpha+1})$.

Once it computes S_M and S_T, the microprocessor 26 determines whether the echoes are from an incoming airplane 12. If S_M is not greater than 24, no airplane 12 has been found and the microprocessor 26 returns to the beginning of the capture mode 62. If the largest sum of echoes, S_M is greater than 24 (74), a "possible" airplane 12 has been located. If a "possible" airplane 12 has been located, the microprocessor checks if S_M/S_T is greater than 0.5 (76), or the three adjacent sectors with the largest sum contain at least half

of all the echoes received during the scan.

If S_M/S_T is greater than 0.5, the microprocessor 26 calculates the location of the center of the echo. (78, 82) The angular location of the center of the echo is calculated as:

$$\alpha_t = \alpha_v + (S_{\alpha+1} - S_{\alpha-1})/(S_{\alpha-1} + S_\alpha + S_{\alpha+1})$$

where S_α is the S_α that gave S_M and a_v is the angular sector that corresponds to that S_α.

The longitudinal position of the center of the echo is calculated as:

$$l_t = (1/n)\ {}_{i=1}\Sigma^{10}\ l_{avi}$$

where the l_{avi} are the measured values, or distances to the object, for the pulses that returned an echo from the sector α_v and where n is the total number of measured values in this sector. (78, 82) Because the largest possible number of measured values is ten, n must be less than or equal to ten.

However, if $S_M/S_T < 0.5$, the echoes may have been caused by snow or other aircraft at close range. If the cause is an aircraft at close range, that aircraft is probably positioned fairly close to the centerline so it is assumed that α_t should be zero instead of the above calculated value and that l_t should be the mean distance given by the three middle sectors. (80) If the distance distribution is too large, the microprocessor 26 has not found an airplane 12 and it returns to the beginning of the capture mode 62. (81).

After calculating the position of the aircraft 12, the system 10 switches to docking mode 64.

Docking Mode

The docking mode 64, illustrated in Fig. 4, includes three phases, the tracking phase 84, the height measuring phase 86 and the identification phase 88. In the tracking phase 84, the system 10 monitors the position of the incoming aircraft 12 and provides the pilot with information about axial location 31 and distance from the stopping point 53 of the plane through the display 18. The system 10 begins tracking the aircraft 12 by scanning horizontally.

Referring to Fig. 8, during the first scan in tracking phase 84, the microprocessor 26 directs the LRF 20 to send out laser pulses in single angular steps, α, or, preferably, at 0.1 degree intervals between:

$$(\alpha_t - \alpha_p - 10) \text{ and } (\alpha_t + \alpha_p + 10)$$

where α_t is determined during the capture mode 62 as the angular position of the echo center and α_p is the largest angular position in the current profile column that contains distance values.

After the first scan, α is stepped back and forth with one step per received LRF

value between:

$(\alpha_s - \alpha_p - 10)$ and $(\alpha_s + \alpha_p + 10)$

where α_s is the angular position of the azimuth determined during the previous scan.

During the tracking phase 84, the vertical angle, ß, is set to the level required for the identified craft 12 at its current distance from the LRF 20 which is obtained from the reference profile Table I . The current profile column is the column representing a position less than but closest to l_t.

The microprocessor 26 uses the distance from the stopping point 53 to find the vertical angle for the airplane's current distance on the profile Table I. During the first scan, the distance, l_t, calculated during the capture mode 62, determines the appropriate column of the profile Table I and thus the angle to the aircraft 12. For each subsequent scan, the microprocessor 26 uses the ß in the column of the profile Table I reflecting the present distance from the stopping point 53. (112)

Using the data from the scans and the data on the horizontal profile Table I, the microprocessor 26 creates a Comparison Table II . Referring to Table II the Comparison Table II is a two dimensional table with the number of the pulse. or angular step number, as the index 91, i, to the rows. Using this index, the following information, represented as columns of the table, can be accessed for each row: l_i 92, the measured distance to the object on this angular step, l_{ki} 93, the measured value compensated for the skew caused by the displacement (equal to l_i minus the quantity s_m, the total displacement during the last scan, minus the quantity i times s_p, the average displacement during each step in the last scan (i.e.) l_i-(s_m-is_p)), d_i 94, the distance between the generated profile and the reference profile (equal to r_{ij}, the profile value for the corresponding angle at the profile distance j, minus l_{ki}), a_i 95, the distance between the nose of the aircraft and the measuring equipment (equal to r_{j50}, the reference profile value at zero degrees, minus d_i), a_e 96, the estimated nose distance after each step (equal to a_m, the nose distance at the end of the last scan, minus the quantity i times s_p), a_d, the difference between the estimated and measured nose distance (equal to the absolute value of a_i minus a_e), and Note 97 which indicates the echoes that are likely caused by an aircraft.

During the first scan in the tracking phase 84, the system 10 uses the horizontal profile column representing an aircraft position, j, less than but closest to the value of l_t. For each new scan, the profile column whose value is less than but closest to (a_m - s_m) is chosen where a_m is the last measured distance to the aircraft 12 and s_m is the aircraft's displacement during the last scan. Additionally, the values of the profile are shifted

sideways by α_s to compensate for the lateral position of the aircraft. (112)

During each scan, the microprocessor 26 also generates a Distance Distribution Table (DDT). This table contains the distribution of a_i values as they appear in the Comparison Table II. Thus, the DDT has an entry representing the number of occurrences of each value of a_i in the Comparison Table II in 1 meter increments between 10 to 100 meters.

After every scan, the system 10 uses the DDT to calculate the average distance, a_m, to the correct stopping point 53. The microprocessor 26 scans the data in the DDT to find the two adjacent entries in the DDT for which the sum of their values is the largest. The microprocessor 26 then flags the Note 97 column in the Comparison Table II for each row containing an entry for a_i corresponding to either of the two DDT rows having the largest sum. (114)

The system 10 then determines the lateral deviation or offset. (116) The microprocessor 26 first sets:

$$2d = \alpha_{max} - \alpha_{min}$$

where α_{max} and α_{min} are the highest and lowest α values for a continuous flagged block of d_i values in the Comparison Table II. Additionally, the microprocessor 26 calculates:

$$Y_1 = \Sigma d_i$$

for the upper half of the flagged d_i in the block and:

$$Y2 = \Sigma d_i$$

for the lower half of the block. Using Y_1 and Y_2, "a" 116 is calculated as:

$$a = k \times (Y_1 - Y_2)/d^2$$

where k is given in the reference profile. If "a" exceeds a given value, preferably set to one, it is assumed that there is a lateral deviation approximately equal to "a". The l_i column of the Comparison Table II is then shifted "a" steps and the Comparison Table II is recalculated. This process continues until "a" is smaller than an empirically established value, preferably one. The total shift, α_s, of the l_i column is considered equal to the lateral deviation or offset. (116) If the lateral offset is larger than a predetermined value, preferably set to one, the profile is adjusted sideways before the next scan. (118, 120)

After the lateral offset is checked, the microprocessor 26, provides the total sideways adjustment of the profile, which corresponds to the lateral position 31 of the aircraft 12, on the display 18. (122)

The microprocessor 26 next calculates the distance to the nose of the aircraft, a_m, as:

$a_m = \Sigma(\text{flagged } a_i)/N$

where N is the total number of flagged a_i. From a_m, the microprocessor 26 can calculate the distance from the plane 12 to the stopping point 53 by subtracting the distance from the LRF 20 to the stopping point 53 from the distance to the nose of the aircraft. (124)

Once it calculates of the distance to the stopping point 53, the microprocessor 26 calculates the average displacement during the last scan, s_m. The displacement during the last scan is calculated as:

$S_m = a_{m-1} - a_m$

where a_{m-1} and a_m belong to the last two scans. For the first scan in tracking phase 84, S_m is set to 0.

The average displacement s_p during each step is calculated as:

$S_p = S_m / P$

where P is the total number of steps for the last scan cycle.

The microprocessor 26 will inform the pilot of the distance to the stopping position 53 by displaying it on the display unit 18, 29. By displaying the distance to the stopping position 29, 53 after each scan, the pilot receives constantly updated information in real time about how far the plane 12 is from stopping.

If the aircraft 12 is in the display area 52, both the lateral 31 and the longitudinal position 29 are provided on the display 18. (126, 128) Once the microprocessor 26 displays the position of the aircraft 12, the tracking phase ends.

Once it completes the tracking phase, the microprocessor 26 verifies that tracking has not been lost by checking that the total number of rows flagged divided by the total number of measured values, or echoes, in the last scan is greater than 0.5. (83) In other words, if more than 50% of the echoes do not correspond to the reference profile, tracking is lost. If tracking is lost and the aircraft 12 is greater than 12 meters from the stopping point, the system 10 returns to the capture mode 62. (85) If tracking is lost and the aircraft 12 is less than or equal to 12 meters from the stopping point 53, the system 10 turns on the stop sign to inform the pilot that it has lost tracking. (85, 87)

If tracking is not lost, the microprocessor 26 determines if the nose height has been determined. (130) If the height has not yet been determined, the microprosessor 26 enters the height measuring phase 86. If the height has already been determined, the microprocessor 26 checks to see if the aircraft has been identified. (132)

In the height measuring phase, illustrated in Fig. 9, the microprocessor 26 determines the nose height by directing the LRF 20 to scan vertically. The nose height is

used by the system to ensure that the horizontal scans are made across the tip of the nose.

To check the nose height, the microprocessor 26 sets ß to a predetermined value β_{max} and then steps it down in 0.1 degree intervals once per received/reflected pulse until it reaches β_{min}, another predetermined value. β_{min} and β_{max} are set during installation and typically are -20 and 30 degrees respectively. After β reaches β_{min} the microprocessor 26 directs the step motors 24, 25 up until it reaches β_{max} . This vertical scanning is done with α set to α_s , the azimuth position of the previous scan.

Using the measured aircraft distance, the microprocessor 26 selects the column in the vertical profile table closest to the measured distance. (140) Using the data from the scan and the data on the vertical profile table, the microprocessor 26 creates a Comparison Table II. Referring to Fig.4, the Comparison Table II is a two dimensional table with the number of the pulse, or angular step number, as an index 91, i. to the rows. Using this index, the following information, represented as columns of the table, can be accessed for each row: l_i 92, the measured distance to the object on this angular step,l_{ki} 93, the measured value compensated for the skew caused by the displacement (equal to l_i minus the quantity S_m, the total displacement during the last scan, minus the quantity i times s_p, the average displacement during each step in the last scan), d_i 94. the distance between the generated profile and thereference profile (equal to r_{ij}, the profile value for the corresponding angle at the profile distance j, minus l_{ki}), a_i 95, the distance between the nose of the aircraft and the measuring equipment (equal to r_{j50}, the reference profile value at zero degrees, minus d_i), a_e 96, the estimated nose distance after each step (equal to a_m, the nose distance at the end of the last scan, minus the quantity i times s_p). a_d, the difference between the estimated and measured nose distance (equal to the absolute value of a_i minus a_e), and Note 97 which indicates echoes that are likely caused by an aircraft 12.

During each scan, the microprocessor 26 also generates a Distance Distribution Table (DDT). This table contains the distribution of a_i values as they appear in the Comparison Table II. Thus, the DDT has an entry representing the number of occurrences of each value of a_i in the Comparison Table II in 1 meter increments between 10 to 100 meters.

After every scan, the system 10 uses the DDT to calculate the average distance, a_m, to the correct stopping point 53. The microprocessor 26 scans the data in the DDT to find the two adjacent entries in the DDT for which the sum of their values is the largest. The microprocessor 26 then flags the Note 97 column in the Comparison Table II for each row containing an entry for a_i corresponding to either of the two DDT rows having the

largest sum. (142)

Once it completes the calculation of the average distance to the correct stopping point 53, the microprocessor 26 calculates the average displacement during the last scan, s_m. The displacement during the last scan is calculated as:

$$s_m = a_{m-1} - a_m$$

where a_{m-1} and a_m belong to the last two scans. For the first scan in tracking phase 84, s_m is set to 0. The average displacement s_p during each step is calculated as

$$s_p = s_m / P$$

where P is the total number of steps for the last scan cycle.

Calculating the actual nose height is done by adding the nominal nose height, predetermined height of the expected aircraft when empty, to the vertical or height deviation. Consequently, to determine the nose height, the system 10 first determines the vertical or height deviation. (144) Vertical deviation is calculated by setting:

$$2d = \beta_{max} - \beta_{min}$$

where β_{max} and β_{min} are the highest and lowest β value for a continuous flagged block of d_i values in the Comparison Table II. Additionally, the microprocessor 26 calculates:

$$Y_1 = \Sigma d_i$$

for the upper half of the flagged d_i in the block and:

$$Y_2 = \Sigma d_i$$

for the lower half of the block. Using Y_1 and Y_2, "a" is calculated as

$$a = k \times (Y_1 - Y_2)/d^2$$

where k is given in the reference profile. If "a"exceeds a given value, preferably one, it is assumed that there is a vertical deviation approximately equal to "a". The l; column is then shifted "a" steps, the Comparison Table II is re-screened and "a" recalculated. This process continues until "a" is smaller than the given value, preferably one. The total shift, β_s of the l_i column is considered equal to the height deviation. (144) The β_j values in the vertical Comparison Table II are then adjusted as $\beta_j + \Delta\beta_j$ where the height deviation $\Delta\beta_j$ is:

$$\Delta\beta_j = \beta_s \times (a_{m\beta} + a_s) / (a_j + a_s)$$

and where $a_{m\beta}$ is the valid a_m value when β_s was calculated.

Once the height deviation is determined, the microprocessor 26 checks if it is bigger than a predetermined value, preferably one. (146) If the deviation is larger than that value, the microprocessor 26 adjusts the profile vertically corresponding to that offset. (148) The microprocessor 26 stores the vertical adjustment as the deviation from the nominal nose height. (150) The actual height of the aircraft is the nominal nose height plus

the deviation. Once it completes the height measuring phase 86, the microprocessor 26 returns to the tracking phase 84.

If the microprocessor 26 has already determined the nose height, it skips the height measuring phase 86 and determines whether the aircraft 12 has been identified. (130, 132) If the aircraft 12 has been identified, the microprocessor 26 checks whether the aircraft 12 has reached the stop position. (134) If the stop position is reached, the microprocessor 26 turns on the stop sign and the system 10 has completed the docking mode 64. (136) If the aircraft 12 has not reached the stop position, the micro-processor 26 returns to the tracking phase 84. (134)

If the aircraft 12 is not identified, the microprocessor 26 checks whether the aircraft 12 is less than or equal to 12 meters from the stopping position 53. (133) If the aircraft 12 not more than 12 meters from the stopping position 53, the system 10 turns on the stop sign to inform the pilot that identi-fication has failed. (135) After displaying the stop sign, the system 10 shuts down.

If the aircraft 12 is more than 12 meters from the stopping point 53; the micropro-cessor 26 enters the identification phase illustrated in Fig.10. (133, 88) In the identification phase 88, the microprocessor 26 creates a Comparison Table II to reflect the results of another vertical scan and the contents of the profile table. (152, 154) Another vertical scan is performed in the identification phase 88 because the previous scan may have provided sufficient data for height determination but not enough for identification. In fact, several scans may need to be done before a positive identification can be made. After calculating the vertical offset 156, checking that it is not too large 158 and adjusting the profile verti-cally corresponding to the offset 160 until the offset drops below a given amount, prefer-ably one, the microprocessor 26 calculates the average distance between marked echoes and the profile and the mean distance between the marked echoes and this average distance. (162)

The average distance d_m between the measured and corrected profile and the deviation T from this average distance is calculated after vertical and horizontal scans as follows:

$$d_m = \Sigma d_i / N$$
$$T = \Sigma \left| d_i - d_m \right| / N$$

If T is less than a given value, preferably 5, for both profiles, the aircraft 12 is judged to be of the correct type provided that a sufficient number of echoes are received. (164) Whether a sufficient number of echoes is received is based on:

N/size > 0.75

where N is the number of "accepted" echoes and "size" is the maximum number of values possible. If the aircraft 12 is not of the correct type, the microprocessor turns on the stop sign 136 and suspends the docking mode 64. Once the microprocessor 26 completes the identification phase 88, it returns to the tracking phase 84.

While the present invention has been described in connection with particular embodiments thereof, it will be understood by those skilled in the art that many changes may be made without departing from the true spirit and scope of the present invention as set forth in the following claims.

Table 1

41

42		78.25	78	77.5	. . .	23
44		5	5	5.6	. . .	10
45		1	2	3	. . .	50
	0	xx	xx	xx	. . .	xx
	1	xx	xx	xx	. .	xx
	2	xx	xx	xx	. . .	xx
	3	xx	xx	xx	. . .	xx
	4	xx	xx	xx	. .	xx
10	5	xx	xx	xx	. . .	xx
	6	xx	xx	xx	. .	xx
	7	xx	xx	xx	. .	xx
	8	xx	xx	xx	. . .	xx
	9	xx	xx	xx	. .	xx
	.					
	.					
	.					
	50	xx	xx	xx	. . .	xx

43

Table II

91 i	92 l_i	93 l_{ki}	94 d_i	95 a_i	96 a_c	97 Note
1	xx	xx	xx	xx	xx	xx
2	xx	xx	xx	xx	xx	xx
3	xx	xx	xx	xx	xx	xx
4	xx	xx	xx	xx	xx	xx
5	xx	xx	xx	xx	xx	xx
6	xx	xx	xx	xx	xx	xx
.						
.						
.						
50	xx	xx	xx	xx	xx	xx
.						
.						
.						
100	xx	xx	xx	xx	xx	xx

WE CLAIM:

1. A system for verifying the shape of a detected object comprising:

means for projecting light pulses in angular coordinates onto an object;

means for collecting light pulses reflected off said object and for determining the detected shape of said object; and

means for comparing said detected shape with a profile corresponding to the shape of a known object and for determining whether said detected shape corresponds to said known shape.

2. The system of claim 1 wherein the light pulses are projected onto a mirror system with means for adjusting the mirror system to project the light pulses outwardly.

3. The system of claims 1- 2 wherein the profile corresponding to the shape of a known object comprises sets of expected reflected pulses at various distances from the stopping point.

4. The system of claims 1-3 further including means for detecting the presence of an object within a capture zone, said detection means comprising:

said adjustable mirror system projects said light pulses outwardly in a predetermined plane such that said projected light pulses will reflect off an object within a capture zone;

means for processing collected light pulses reflected off said object within the capture zone to enable detection of the presence of such object.

5. The system of claim 4 wherein said capture zone comprises an area within said plane of said projected light pulses, said area being defined as a predetermined angular configuration relative to an axis extending from said mirror system and at predetermined axial distances from said mirror system, said area being divided into multiple angular sectors defined by rays extending outwardly from said mirror system. 6. The system of claims 4-5 wherein said capture zone is repetitiously scanned with said light pulses projected in said predetermined plane until an object is detected based on the processing of said collected light pulses reflected off said object.

7. The system of claim 4-6 wherein said object is an airplane having a nose section positioned a predetermined vertical height above a surface of an airfield.

8. The system of claims 4-7 wherein said adjustable mirror system projects said light pulses at a predetermined angle relative to said surface of said airfield so that said light pulses intersect with said nose section of said airplane.

9. The system of claims 2-8 wherein said adjustable mirror system is operated by

step motors under the control of a programmed microprocessor.

10. The system of claims 2-9 including a microprocessor for adjusting the mirror system so that the projected light pulses scan the capture zone and a data storage device for receiving data concerning the light pulses reflected off an object, said data storage device containing comparative information for comparison with the received data and said microprocessor employing said received data and said comparative information to determine whether an object has entered the capture zone.

11. The system of claim 10 wherein said received data includes the number of pulses reflected off a detected object in each sector of the capture zone and said comparative information includes data for determining the distance between a detected object and said means for collecting the light pulses.

12. The system of claims 9-10 wherein:

the microprocessor totals the number of reflected pulses in each scan of said capture zone;

said microprocessor determines the largest sum of reflected pulses for three adjacent sectors; and

said microprocessor determines that an object has been detected if the largest sum of reflected pulses for three adjacent sectors is at least a predetermined minimum number out of a total number of pulses projected within said three adjacent sectors and the number of reflected pulses in the three sectors with the largest sum is more than half of the total number of reflected pulses in the scan of said capture zone.

13. The system of claims 1-12 further including means for tracking an incoming object, said tracking means comprising:

means for detecting the position of said incoming object relative to an imaginary axial line projecting from a predetermined point and for detecting the distance between said object and said predetermined point whereby tracking of the location of said object is enabled.

14. The system of claim 13 wherein:

a comparison table is generated containing information about collected light pulses and said information is compared with a profile table indicating the shape of known objects;

a distance distribution table is generated recording the distribution of distances from the object to said collection means for each collected light pulse; and

an average distance is calculated from the detected position of said object to a desired stopping position for said object.

15. The system of claims 14 wherein:
the average distance to the stopping position is calculated by averaging the distance to said stopping position recorded for the entries in the comparison table corresponding to the two adjacent entries in the distance distribution table having the largest sum.

16. The system of claims 13-15 including a display indicating the distance from the object to a stopping point, the type of object and the location of the object compared to said imaginary axial line.

17. The system of claims 14-16 wherein the average stopping distance is communicated to a computer on board the aircraft allowing that computer to stop the aircraft when said aircraft reaches said stopping position.

18. The system of claims 1-17 further including means for directing said projected light pulses onto a calibration element positioned in a known angular direction and at a known distance from said means for directing said projected light for purposes of calibration of said system.

19. The system of claim 18 wherein the means for directing said projected light comprises a second mirror system.

20. The system of claims 18-19 wherein:
said light pulses are reflected off said object and are received at a detector;
determining a detected angular direction of the object relative to said light source based on said pulses received at said detector and in accordance with predetermined angular parameters;
comparing said detected angular direction with said known angular direction to determine whether said detected angular direction corresponds to said known angular direction.

21. The system of claim 20 further comprising:
adjusting the angular parameters if said detected angular direction and said known angular direction do not correspond so that the detected angular direction is caused to correspond essentially to the known angular direction.

22. The system of claims 20-21 further comprising:
determining the detected distance of the object from said light source based on predetermined distance parameters; comparing said detected distance with

a known distance of said object from said light source to determine whether said detected distance corresponds to said known distance.

23. The system of claims 20-22 further comprising:

adjusting the distance parameters if said detected distance and said known distance do not correspond so that the detected distance is caused to correspond essentially to the known distance.

24. The system of claims 18-20 wherein the angular direction and distance of said calibration means from said means for directing said projected light in a horizontal plane are calibrated while the angular direction and distance of said calibration means from said means for directing said projected light in a vertical plane are held constant.

25. The system of claims 1-24 wherein said light pulses are laser light pulses.

26. The system of claims 1-25 wherein said profile is stored in a memory device.

27. A system for tracking an incoming object comprising:

means for generating light pulses;

means for projecting said pulses outwardly onto an incoming object and for reflecting said light pulses off said object;

means for collecting the light pulses reflected off of said object;

means for detecting the position relative to an imaginary axial line projecting from a predetermined point and for detecting the distance between said object and said predetermined point whereby tracking of the location of said object is enabled.

28. The tracking system of claim 27 wherein the light pulses are laser light pulses.

29. The tracking system of claim 27-28 wherein the light pulses are projected onto a mirror system with means for adjusting the mirror system to project the light pulses outwardly onto an incoming object.

30. The tracking system of claims 27-29 wherein a microprocessor provides the means for monitoring the location of said object.

31. The tracking system of claims 27-30 wherein

a comparison table is generated reflecting information about the laser scan and is compared with a profile table indicating the shape of known objects;

a distance distribution table is generated recording the distribution of distances from the nose of the object to the measuring device for each reflected pulse; and

an average distance to a desired stopping position is calculated.

32. The tracking system of claims 27-31 wherein
the average distance to the stopping position is calculated by averaging the distance to said stopping position recorded for the entries in the comparison table corresponding to the two adjacent entries in the distance distribution table having the largest sum.

33. The tracking system of claims 27-32 wherein a display shows the distance from the object to the stopping point, the type of object and the location of the object compared to center.

34. The tracking system of claims 27-33 wherein the average stopping distance is communicated to a computer on board the aircraft allowing that computer to stop the aircraft when said aircraft reaches said stopping position.

35. A method for verifying the shape of a detected object comprising:
projecting light pulses in angular coordinates onto an object;
reflecting said pulses back to a detector and determining the detected shape of the object based on said reflected pulses;
comparing said detected shape with a profile corresponding to the shape of a known object; and
determining whether said detected shape corresponds to said known shape.

36. The method of claim 35 wherein the profile corresponding to the shape of a known object comprises sets of expected reflected pulses at various distances from the stopping point.

37. The method of claim 35-36 wherein a microprocessor is programmed to identify an object.

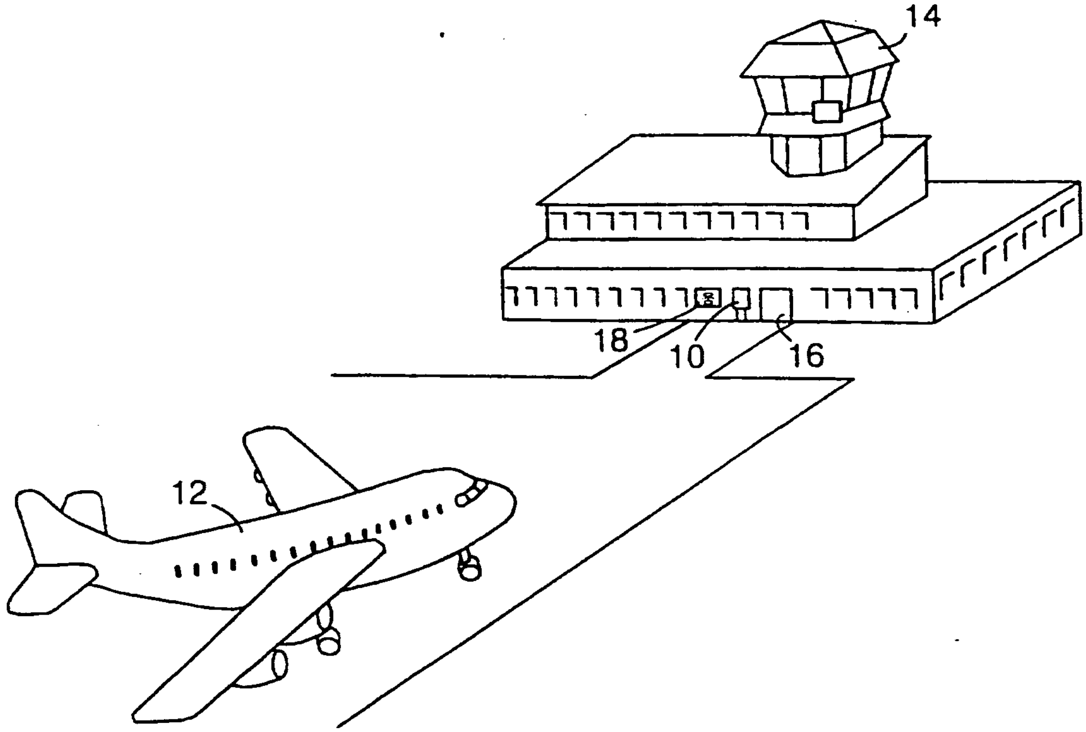


FIG.1

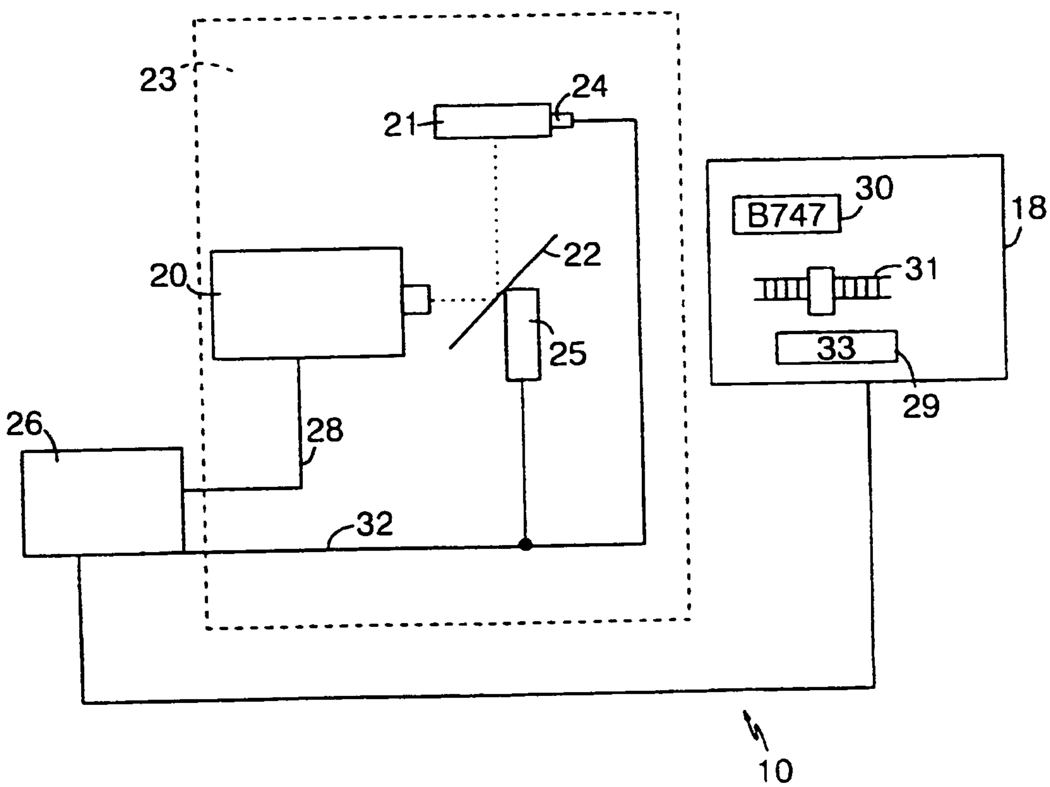


FIG.2

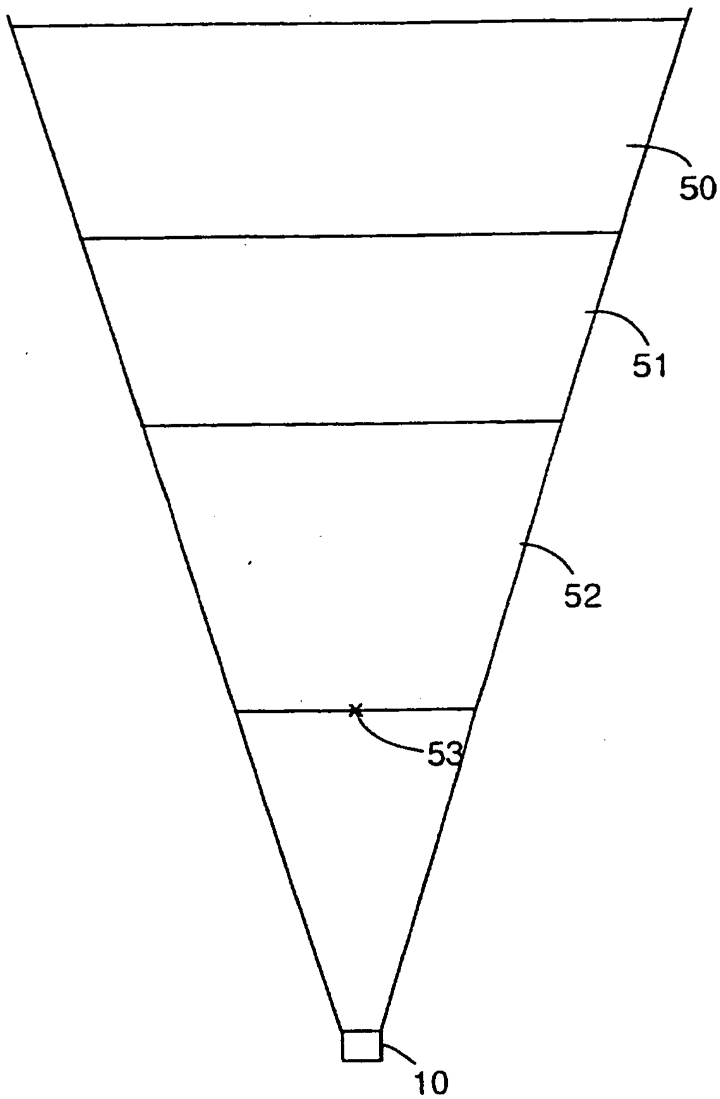


FIG.3

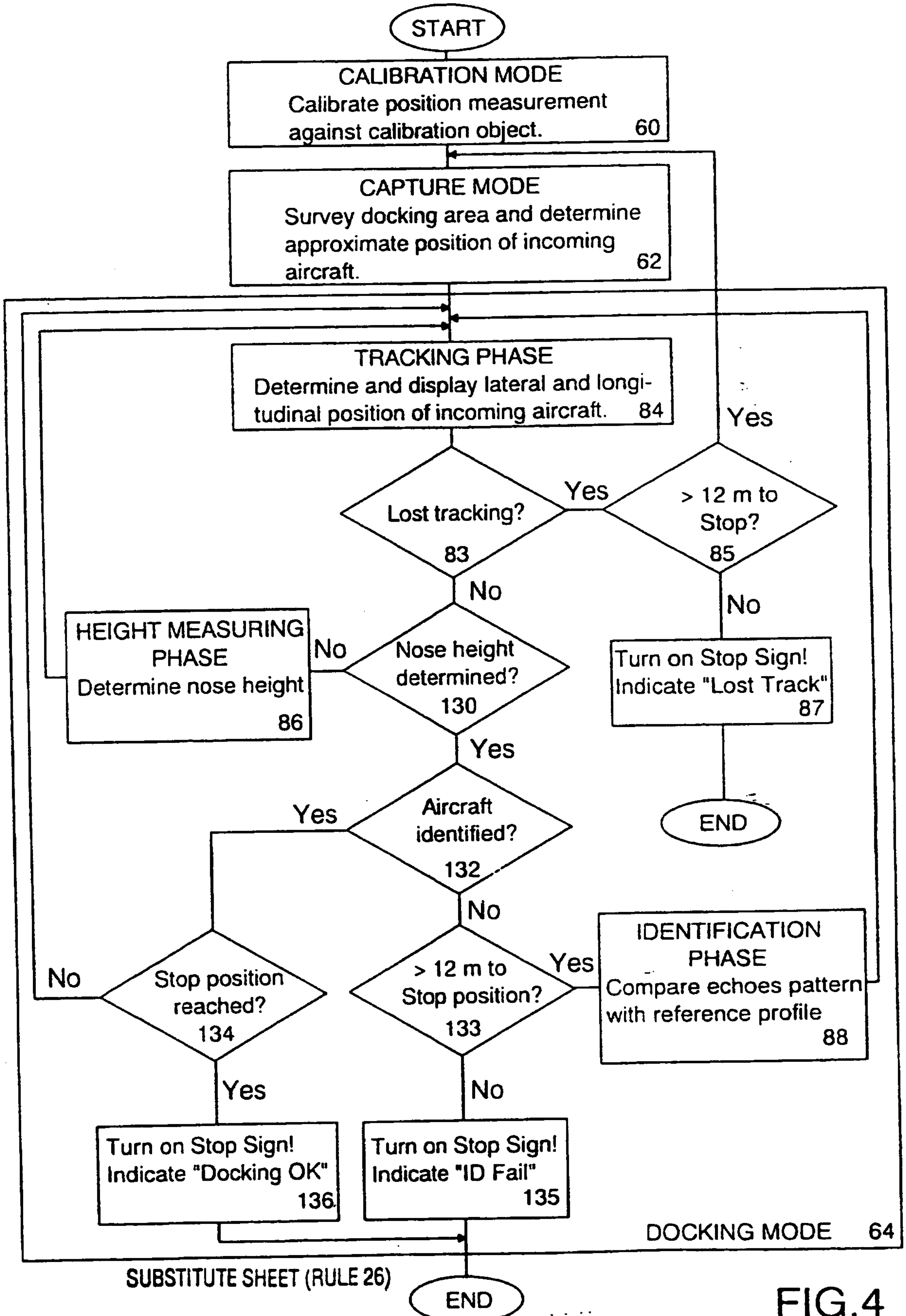


FIG.4

SUBSTITUTE SHEET (RULE 26)

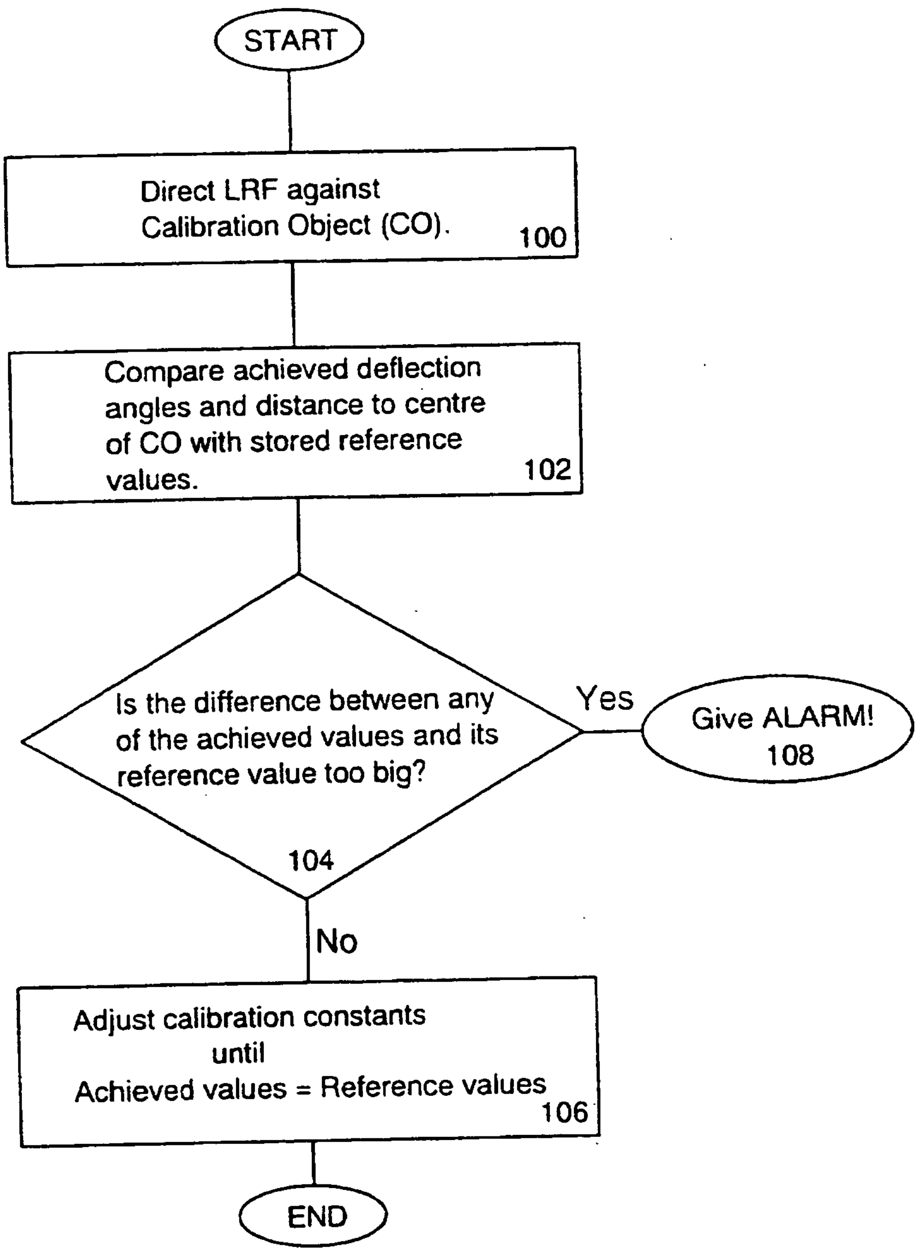

START
Direct LRF against
Calibration Object (CO).
100
Compare achieved deflection
angles and distance to centre
of CO with stored reference
values.
102
Is the difference between any
of the achieved values and its
reference value too big?
104
Yes
Give ALARM!
108
No
Adjust calibration constants
until
Achieved values = Reference values
106
END

FIG.5

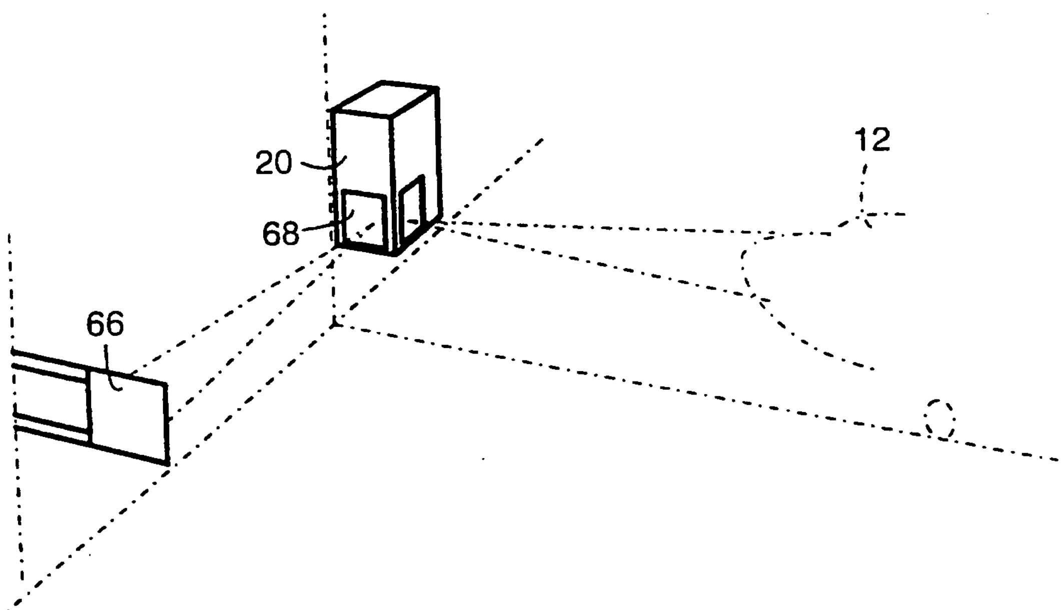


FIG.6

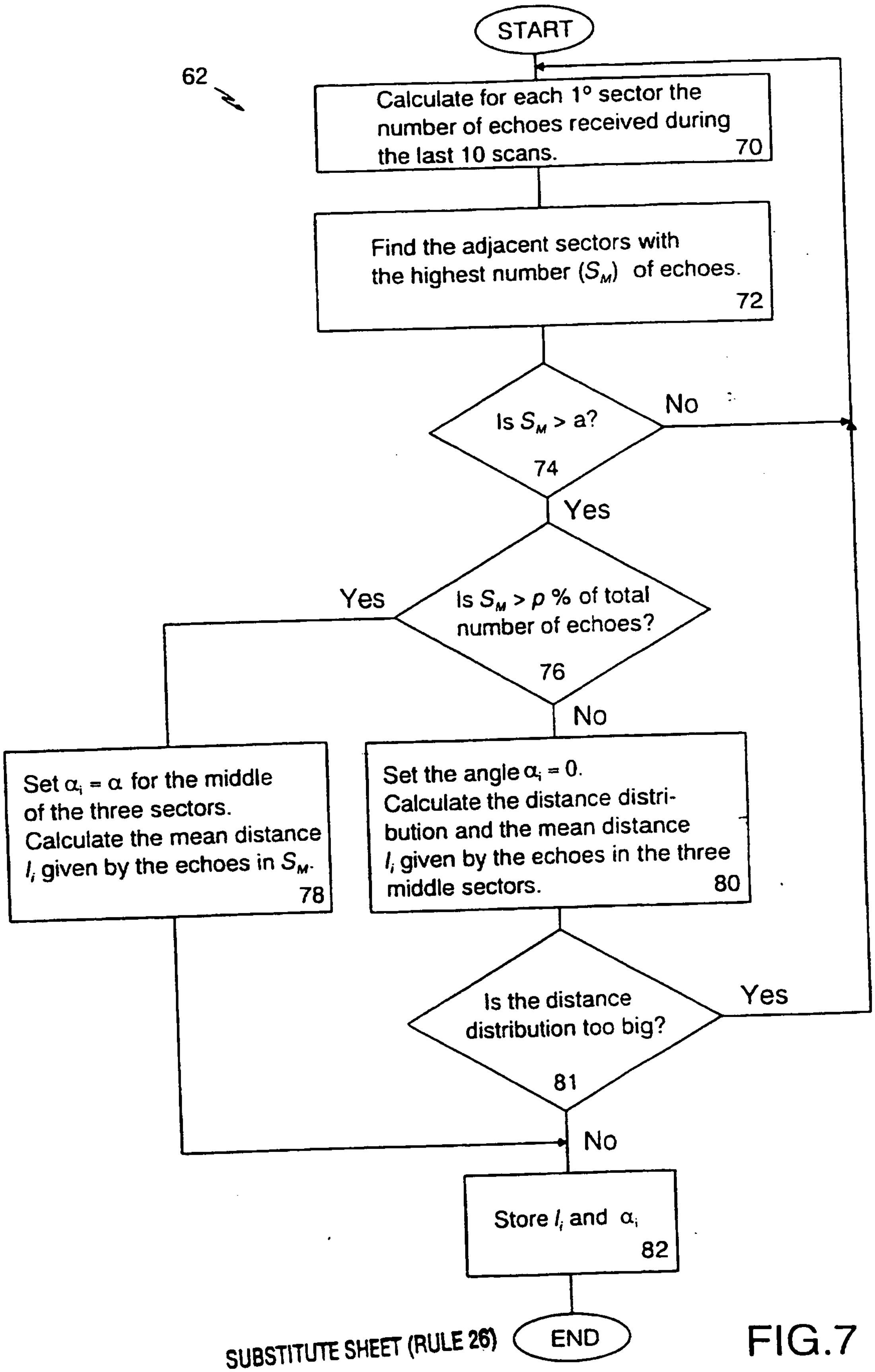

START
62
Calculate for each 1° sector the number of echoes received during the last 10 scans. 70
Find the adjacent sectors with the highest number (S_M) of echoes. 72
Is S_M > a? 74
No
Yes
Is S_M > p % of total number of echoes? 76
Yes
No
Set $\alpha_i = \alpha$ for the middle of the three sectors. Calculate the mean distance l_i given by the echoes in S_M. 78
Set the angle $\alpha_i = 0$. Calculate the distance distribution and the mean distance l_i given by the echoes in the three middle sectors. 80
Is the distance distribution too big? 81
Yes
No
Store l_i and α_i 82
END

FIG.7

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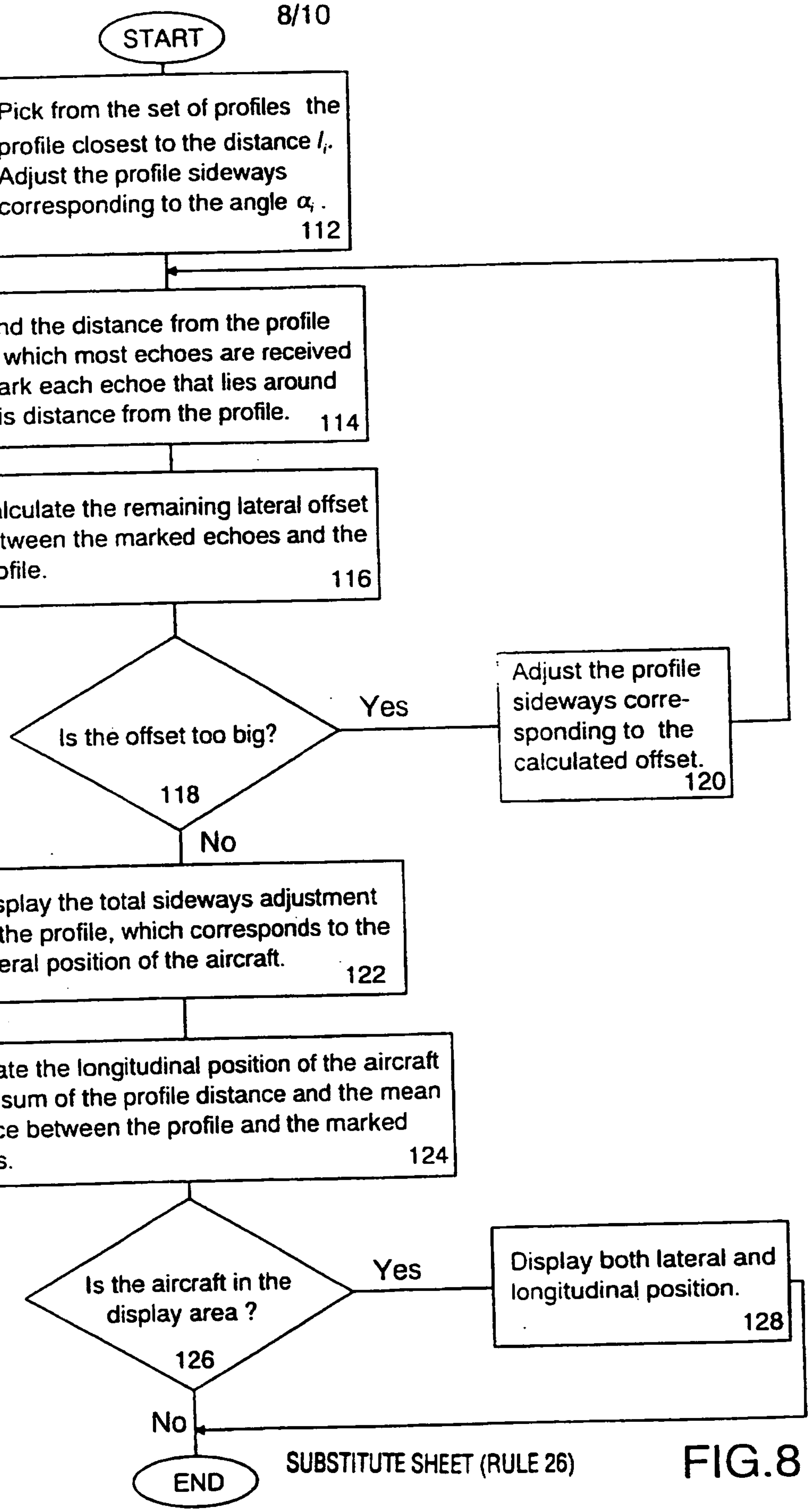

SUBSTITUTE SHEET (RULE 26)

FIG.8

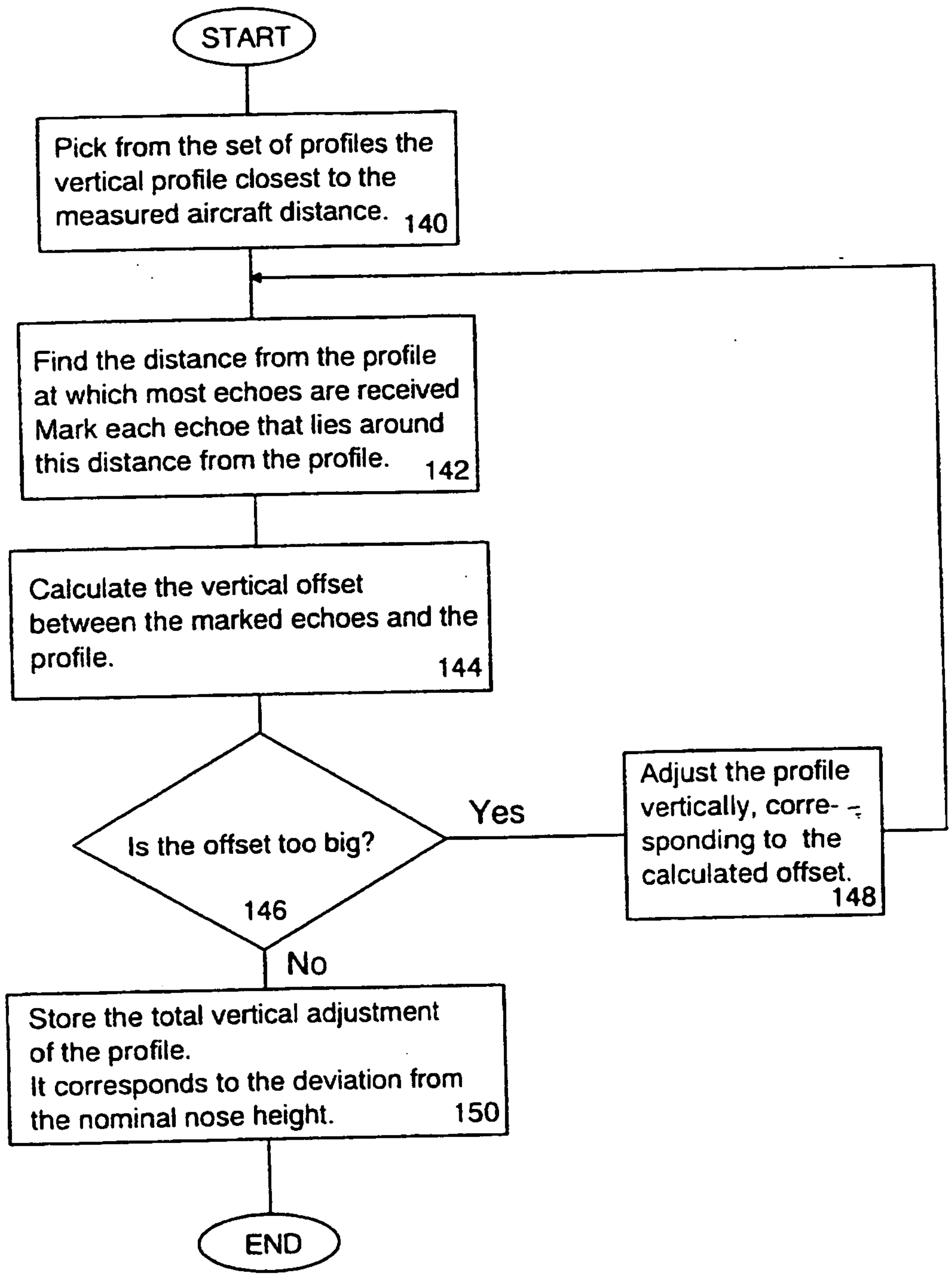
START
Pick from the set of profiles the vertical profile closest to the measured aircraft distance. 140
Find the distance from the profile at which most echoes are received Mark each echoe that lies around this distance from the profile. 142
Calculate the vertical offset between the marked echoes and the profile. 144
Is the offset too big? 146
Yes
Adjust the profile vertically, corre- sponding to the calculated offset. 148
No
Store the total vertical adjustment of the profile.
It corresponds to the deviation from the nominal nose height. 150
END

FIG.9

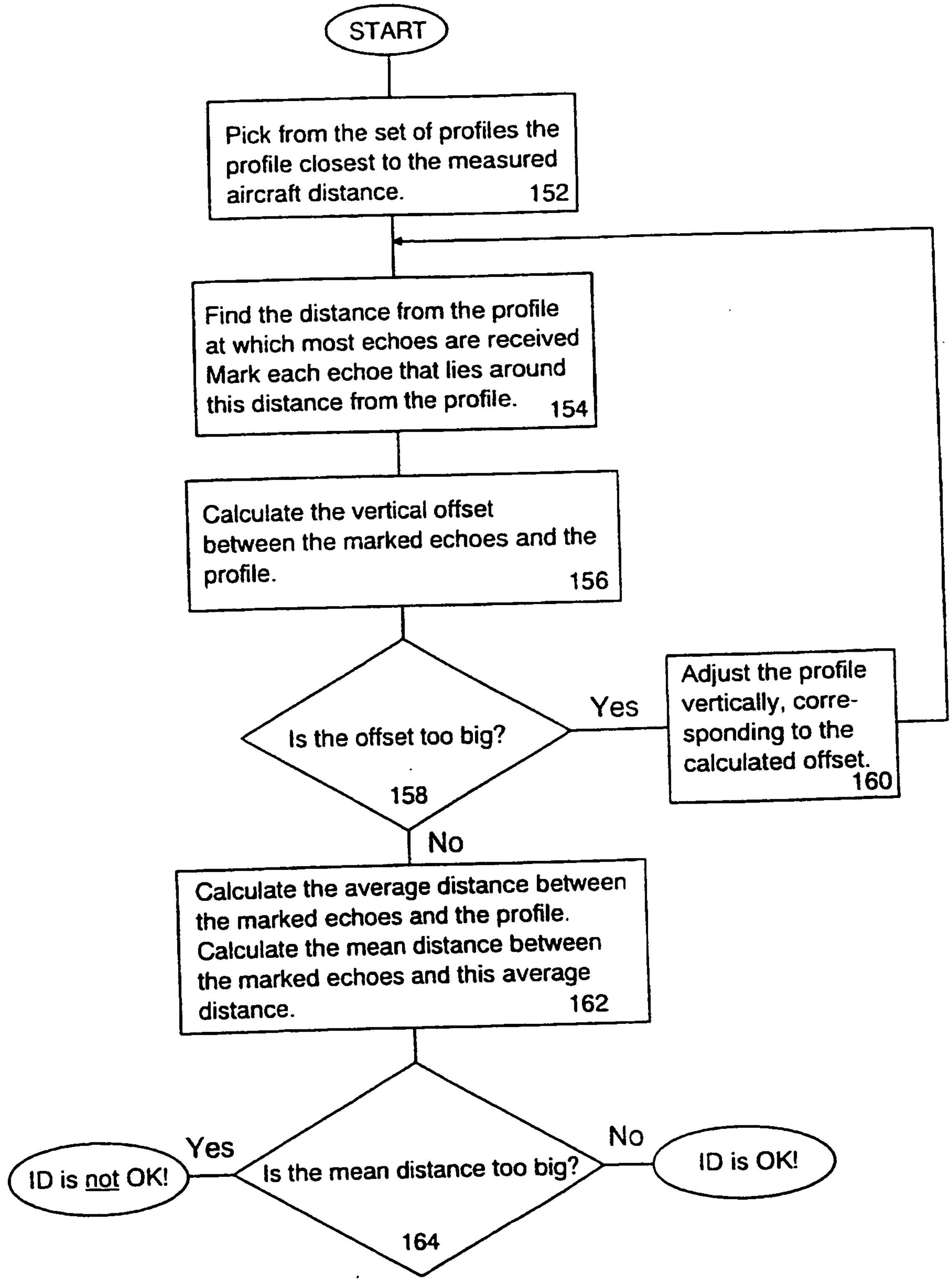
START
Pick from the set of profiles the profile closest to the measured aircraft distance. 152
Find the distance from the profile at which most echoes are received Mark each echoe that lies around this distance from the profile. 154
Calculate the vertical offset between the marked echoes and the profile. 156
Is the offset too big? 158
Yes
Adjust the profile vertically, corresponding to the calculated offset. 160
No
Calculate the average distance between the marked echoes and the profile. Calculate the mean distance between the marked echoes and this average distance. 162
Is the mean distance too big? 164
Yes
ID is not OK!
No
ID is OK!

FIG.10

INTERNATIONAL SEARCH REPORT

Internal Application No
PCT/SE 94/00968

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G08G5/06 B64F1/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 G08G G08B B64F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE,A,43 01 637 (DEUTSCHE AEROSPACE AG) 11 August 1994 see the whole document ---	1-11,13, 16,17, 25-30, 33,35-37
X	US,A,4 319 332 (MEHNERT) 9 March 1982	1-6,13, 16,18, 25-30, 35-37
A	see column 6, line 25 - line 45; figures 1,2 see column 8, line 15 - line 29 see column 11, line 14 - column 16, line 8; figures 5,6 see abstract; claims --- -/--	7,8,10, 11,33

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 June 1995	22.06.95
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax (+31-70) 340-3016	Authorized officer Reekmans, M

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DE,A,40 09 668 (SIEMENS AG) 2 October 1991 see the whole document ---	7,8,10, 11,33
A	EP,A,0 035 101 (ELTRO GMBH GESELLSCHAFT FÜR STRAHLUNGSTECHNIK) 9 September 1981 see the whole document ---	2,4-6,9, 10
A	DATABASE WPI Section EI, Week 9332 Derwent Publications Ltd., London, GB; Class S02, AN 93-256658 & SU,A,1 753 273 (URALS EXPER MECH WKS) , 7 August 1992 see abstract ---	2,4-6,9
E	DATABASE WPI Section EI, Week 9514 Derwent Publications Ltd., London, GB; Class T04, AN 95-105467 & SE,A,9 301 843 (GUSTAVSSON K) , 13 December 1994 see abstract -----	1,4-8, 35,37

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/SE 94/00968

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		AU-A-	4659879	01-11-79
		CH-A-	641583	29-02-84
		FR-A,B	2424594	23-11-79
		GB-A,B	2021893	05-12-79
		JP-A-	54143097	07-11-79
		NL-A-	7902139	30-10-79
		SE-A-	7903699	29-10-79
DE-A-4009668	02-10-91	NONE		
EP-A-35101	09-09-81	DE-A-	3007893	10-09-81